THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. II.

No. V.—MAY, 1915.

ORIGINAL ARTICLES.

I.—Eminent Living Geologists.

Aubrey Strahan, M.A., Sc.D. (Camb.), F.R.S., Hon. LL.D. Toronto, V.P.G.S.; Director of the Museum of Practical Geology and Geological Survey of Great Britain.

(WITH A PORTRAIT, PLATE VII.)

THE records of the Geological Survey of Great Britain date back nearly as far as the first public recognition of geology as a science in this country.

Topographical map-making by the Ordnance Survey commenced in 1784, but it was not until about 1830, when the Director of Ordnance happened to see the excellent maps of the mining districts of Cornwall, the unaided work of De la Beche, that he wisely determined that the mineral delineation should be carried out upon the Ordnance Maps, a task which he induced De la Beche to undertake. Thus initiated, under the support of Major-General T. F. Colby, the Director of Ordnance, the Geological Survey commenced its career in Devon and Cornwall long before it had a local habitation and hardly a name. But through the influence of Government in 1837, Sir Henry De la Beche obtained a house in Craig's Court, Charing Cross, which became "The Museum of Economic Geology", and "The Mining Record Office" later on.

With but few assistants (until 1840) De la Beche traversed many thousand miles, hammer in hand, producing maps which have been the admiration of all who have had occasion to consult them, and thus laid the foundation of the Geological Survey of the United Kingdom and of the Museum of Practical Geology, which was opened in Jermyn Street by the Prince Consort in 1851. Although now shorn of its School of Mines and of its Irish Branch, this building is still the Museum of Practical Geology and the headquarters of the Geological Survey of Great Britain.

For nearly a century (1830–1915), from the date of its genesis under Sir Henry De la Beche, the Geological Survey has enjoyed the unrivalled advantage of a succession of distinguished scientific Directors, all of whom were experienced practical geologists, who had made their mark in the field as well as in the laboratory before reaching the chieftainship of the Royal hammerers.

Sir Henry De la Beche, the founder of the Survey, who passed away in 1855, was followed by Sir Roderick I. Murchison, whose name was already widely known, having been elected twice as

President of the Geological Society, and who left his mark as the author of *The Silurian System* and *The Geology of Russia*. Upon his decease in 1871, the office was filled by Sir Andrew Ramsay, who had been a member of the Survey since 1841, and local Director since 1845, his associates having been Sir Henry James, Dr. Oldham, Professor Jukes, Edward Forbes, A. R. C. Selwyn, Sir William Logan, John Phillips, and other famous geologists. Although only ten years Director-General he had been on the staff for forty years. On his retirement in 1881 at the age of 67, a third eminent Scottish geologist, Sir Archibald Geikie, became Director-General. He had already served on the Scottish Survey for twenty-six years, and at the time of his retirement in 1901 had completed forty-six years of service.

In the appointment of his successor consideration was paid to the special importance of the work of the modern science of petrography in the Geological Survey. For his eminent qualifications in this subject Dr. J. J. Harris Teall had been invited to join the Survey in 1888, and was selected as Director in 1901. Dr. Teall retired on the completion of his 65th birthday on January 5, 1914. (See GEOL. MAG., 1909, pp. 1–8.)

Dr. Aubrey Strahan, the subject of this memoir, and the sixth Director since the establishment of the Geological Survey, has already attained a long and distinguished period of service and added largely to its Records, especially in the investigation of the British Coal-measures and the making of those splendid maps embodying the results of many years of careful and detailed field-work.

Born in London on April 20, 1852, Aubrey Strahan is the fifth son of William Strahan and Anne Dorothea Strahan (only child of Sir George Fisher). He spent his boyhood at Sidmouth, and received his early education at the Rev. W. T. Browning's school at Thorpe Mandeville, Northamptonshire. At 13 he was sent to Eton until 1870. During his school-days at Eton the Chemical Laboratory was built, and a prize for Chemistry (probably the first prize ever given at Eton for any branch of Natural Science) was won by him. A. Strahan proceeded to St. John's College, Cambridge, in 1870 (where his father had also studied). His interest in geology had been stimulated by the Rev. Osmond Fisher (his mother's first cousin), and his first course of the science was in Professor Bonney's lecture-room, where so many geologists received their early training.

A. Strahan graduated in 1875, and on May 12 of that year was appointed to the Geological Survey under Professor Sir Andrew Ramsay. He commenced his field-work in South Lancashire, and proceeded thence into Cheshire. After completing the surveying of the country around Chester he was engaged upon the Lower Carboniferous rocks of Flintshire with their metalliferous veins, the Silurian rocks of the Clwydian range, and the Trias of the Vale of Clwyd, a deep faulted trough of which the structure was then unknown.

In 1883, Strahan was transferred to Lincolnshire to assist in completing the last of the *Old Series* of 1 inch maps. In the two following years he was sent to the neighbourhood of Kendal and Sedbergh, and in 1886 revised the mapping of the Coal-measures, the

Cambrian and pre-Cambrian rocks, near Nuneaton, in order to make the corrections on the map rendered necessary by the discoveries then recently made by Professor Lapworth. Later on in the same year the mines of a part of Derbyshire were examined for the second edition of the Survey memoir on North Derbyshire.

In the latter part of 1886 Mr. Strahan commenced the 6 inch survey of the southern part of the Isle of Wight, and in 1887 he continued the work into the Isle of Purbeck. In 1891, it having been represented in the House of Commons by Sir Hussey Vivian (afterwards Lord Swansea) that the geological maps of the South Wales Coal-field were obsolete, the re-survey of that important area was commenced by Strahan and carried on continuously to its completion, save for two brief interruptions, one to the Isle of Man in 1892 and the other in the Cumberland Coal-field in 1894.

In 1886 Aubrey Strahan married Fanny Evelyn Margaret, daughter of the late Edward H. Roscoe.

In addition to his important work in the field as a Geological Surveyor, Dr. Strahan has contributed upwards of thirty-five memoirs to the publications of the Geological Survey between 1881 and 1915 (the titles of which appear at the end of this notice); but his scientific activities extended far beyond his official duties. For instance, he wrote an appendix to Major Conyngham's Pendulum Observations in India, and published numerous papers in the Quarterly Journal of the Geological Society, including two Presidential Addresses (1913–14). Since 1881 he has written many papers for the Geological Magazine (see list). In 1905 he prepared an important Report on the Coal-fields of Lancashire, Cheshire, and North Wales for the Royal Commission on Coal Supplies.

In 1913 Dr. Strahan was present at the International Congress at Toronto, and contributed the British Section to the Canadian volumes on the 'World's Coal Resources', published last year. As will be seen by the titles of his papers, his contributions to geological science were many and varied, but those which relate to the coal formations of Great Britain have a special importance in connexion with the unexplored areas which lie outside the known fields and await to be exploited in the future.

In 1875 he was elected a Fellow of the Geological Society, and has for many years served upon the Council. He filled the office of Treasurer (1909–12) and of President (1912–14). He was elected to the Royal Society in 1903 and has been on its Council (1909–10).

As a Fellow of the Royal Geographical Society, he was not only on the Council but acted as Chairman of the Research Department. He is an Honorary Member of the Chester Society of Natural Science and of the North of England Institute of Engineers. He accompanied the Total Eclipse Expedition to Vadso in 1896, and visited a section in the glacial deposits of Palæozoic age, also the raised beaches on the Varanger Fiord, and described them both at the Geological Society on his return. He served as President of Section C of the British Association at Cambridge in 1904, and in 1909 attended the meeting at Winnipeg, taking the opportunity to visit Vancouver. In 1910 he attended the International Geological

Congress in Stockholm and took part in an expedition to Spitzbergen. Three years later he attended the same Congress at Toronto as delegate from the British Government and as representative of the Geological Society and the Geological Survey. He was elected a Vice-President of the Congress, and received the honorary degree of LL.D. at the University of Toronto. On this occasion he took part in an excursion through New Brunswick and Nova Scotia. Dr. Strahan was made a member of the Royal Commission on Coal Supply in 1903 and furnished the Report on the Lancashire and Cheshire coal areas and on the concealed coal-fields of England and Wales (apart from the Midlands). In the same year he made a report to the Royal Commission on Arsenical Poisoning.

Out of the long list of famous British geologists who, by their labours in the past century, have so largely contributed to the building up of our science, a great part of them will also be found to have had a share in the making of the Geological Survey of this country. The present Director, Dr. Aubrey Strahan, must feel much gratification that in this task he also has contributed no mean share, both in the completion of its cartography and its numerous published memoirs, whilst as our leading authority on the great and important subject of the economics of our coal-fields he has made for himself a special name. He has carefully carried on his geological studies both at home and abroad, and possesses the experience won by long service and extended observation. But for the present sad war, which has disarranged all our peaceful enterprises, much attention would have been given at the present time by the Government to the anxious 'question of the hour', the extent and duration of our coal-supply.

We may sincerely congratulate the staff of the Geological Survey that in their present Director they have a man who has achieved his position by long years of earnest labour, and who is thoroughly conversant with their work and in sympathy with themselves.

List of Geological Survey Memoirs and Publications by Dr. Aubrey Strahan, M.A., F.R.S.

1881. Geology of Chester.
Geology of Prescot: by E. Hull; third edition, with additions by A. Strahan.
1885. Geology of Rhyl, Abergele, and Colwyn.
1887. Geology of North Derbyshire: by A. H. Green and others; second edition by A. H. Green and A. Strahan.
1888. Geology of Kendal, Sedbergh, Bowness, and Tebay: by W. T. Aveline and T. McK. Hughes; second edition, revised and enlarged, by A. Strahan.
Geology of the Country around Lincoln: edited and in part written by A. Strahan.
1889. Geology of the Isle of Wight: by H. W. Bristow; second edition, revised and enlarged, by C. Reid and A. Strahan.
1890. Geology of Flint, Mold, and Ruthin.
Geology of the Country around Ingleborough: edited and in part written by A. Strahan.
1891. Geology of Mallerstang: edited and in part written by A. Strahan.
1898. Geology of the Isle of Purbeck and Weymouth.
Supplement to the Memoirs on the Geology of Flint, Mold, and Ruthin.

1899. The Country around Newport.
1900. The Country around Abergavenny : with W. Gibson.
1901. The Country around Cardiff : with T. C. Cantrill.
1903. The Country around Pontypridd and Maestêg : with R. H. Tiddeman and W. Gibson.
1904. The Country around Merthyr Tydfil : with W. Gibson and T. C. Cantrill.
The Country around Bridgend : with T. C. Cantrill.
1906. Guide to the Model of the Isle of Purbeck.
1907. The Country around Swansea.
The Geology of West Gower.
The Country around Ammanford : with T. C. Cantrill, E. E. L. Dixon, and H. H. Thomas.
1908. The Coals of South Wales : with W. Pollard.
1909. The Country around Newport, second edition.
The Country around Carmarthen, with T. C. Cantrill, E. E. L. Dixon, and H. H. Thomas.
1910. Guide to the Model of Ingleborough.
1911. On a Deep Channel of Drift at Saham Toney ; Summary of Progress for 1910.
1912. The Country around Cardiff : with T. C. Cantrill ; second edition.
On a Boring for Coal at Ebbsfleet ; Summary of Progress for 1911.
1913. On a Boring at Batsford ; ibid.
1914. Notes on Sources of Temporary Water Supply in the South of England and neighbouring parts of the Continent.
On the Country around Haverfordwest : with T. C. Cantrill, E. E. L. Dixon, H. H. Thomas, and O. T. Jones.
1915. The Coals of South Wales, second edition : with W. Pollard ; in the press.
On a Boring at Whittlesford ; Summary of Progress for 1914 ; in the press.

List of Published Papers communicated to Societies and Journals apart from the Publications of the Geological Survey.

1879. "On the Occurrence of Pebbles with Upper Ludlow Fossils in the Lower Carboniferous Conglomerates of North Wales" : Quart. Journ. Geol. Soc., vol. xxxv, p. 269 (with A. O. Walker).
"On some Glacial Striæ on the Coast of North Wales" : Proc. Liverpool Geol. Soc., vol. iv, p. 44.
1881. "On the Lower Keuper Sandstone of Cheshire" : Geol. Mag., 1881, pp. 396, 574.
"On the Discovery of Coal-measures under New Red Sandstone and on the so-called Permian Rocks of St. Helens, Lancashire" : Geol. Mag., 1881, p. 433.
1882. "On the Channel Tunnel" : *Nature*, vol. xxv, p. 463.
1883. "On the Movements of Air in Fissures and the Barometer" : *Nature*, vol. xxvii, p. 375.
1884. "The Denudations of North Wales" : Proc. Chester Soc. Nat. Science, pt. iii, p. 38.
1885. "The Geology of Cheshire" : Proc. Inst. Iron and Steel.
1886. "On the Glaciation of South Lancashire, Cheshire, and the Welsh Border" : Quart. Journ. Geol. Soc., vol. xlii, p. 369.
"Notes on the Relations of the Lincolnshire Carstone" : ibid., vol. xlii, p. 486.
"On the Rocks surrounding the Warwickshire Coal-field and on the Base of the Coal-measures" : Geol. Mag., 1886, p. 540.
1887. "On Explosive Slickensides" : Geol. Mag., 1887, p. 400.
1891. "On a Phosphatic Chalk with *Belemnitella quadrata* at Taplow" : Quart. Journ. Geol. Soc., vol. xlvii, p. 356.
1895. "On Overthrusts of Tertiary Date in Dorset" : Quart. Journ. Geol. Soc., vol. li, p. 549.

1896. "On a Phosphatic Chalk with *Holaster planus* at Lewes": Quart. Journ. Geol. Soc., vol. lii, p. 563.
"On Submerged Land-surfaces at Barry, Glamorganshire": ibid., vol. lii, p. 474.
1897. "On the Glacial Phenomena of Palæozoic age in the Varanger Fiord": Quart. Journ. Geol. Soc., vol. liii, p. 137.
"The Raised Beaches and Glacial Deposits of the Varanger Fiord": ibid., p. 147.
1898. "On the Revision of South Wales and Monmouthshire by the Geological Survey": GEOL. MAG., 1898, p. 488.
1899. "On the Age of the Vale of Clwyd": GEOL. MAG., 1899, p. 111.
"On an Abnormal Section of Chloritic Marl at Mupe Bay, Dorset": ibid., p. 319.
1901. "On the Passage of a Seam of Coal into a Seam of Dolomite": Quart. Journ. Geol. Soc., vol. lvii, p. 297.
"On the Origin of Coal": GEOL. MAG., 1901, p. 29.
1902. "On the Origin of the River System of South Wales and its connection with that of the Severn and the Thames": ibid., vol. lviii, p. 207.
1904. Presidential Address to Section C of the British Association: Rep. Brit. Assoc. for 1904.
1905. Report on the Coal-fields of Lancashire, Cheshire, and North Wales, and on Concealed and Unproved Coal-fields, for the Royal Commission on Coal Supplies.
1906. "Investigation of Rivers" (with others): Geog. Journ., 1st Rep., 1908; 2nd Rep., 1909; 3rd Rep., 1910; 4th Rep., 1911; Final Report in the press.
1908. Appendix to paper on the Pendulum Observations in India by Major G. P. L. Conyngham: Survey of India, Professional Papers, No. 10.
1910. "Glacial Phenomena of South Wales": Rep. Brit. Assoc. for 1909, p. 475.
"The Geology of South Wales": Geol. Assoc., Jubilee vol., p. 826.
1913. Presidential Address ["On the Palæozoic Platform"] to the Geological Society of London: Quart. Journ. Geol. Soc., vol. lxix, p. 70.
1914. Presidential Address ["On Problems of Post-Glacial Denudation"] to the Geological Society of London: Quart. Journ. Geol. Soc., vol. lxx, p. 59.
"The Subdivisions and Correlation of the Pre-Cambrian Rocks of the British Isles": Internat. Geol. Congress, Twelfth Session (1913), Canada, *Compte-rendu* (1914), p. 339.
"On the Coal Resources of Great Britain": Internat. Geol. Congress, Twelfth Session (1913), Canada; "The Coal Resources of the World," p. 597.

II.—Differential Movement in East Anglia in Tertiary Times.

By P. G. H. Boswell, B.Sc., D.I.C., F.G.S., Imperial College of Science and Technology, South Kensington.

THE sudden change of strike of the Chalk in South-East Suffolk, exceeded only in abruptness at the western limit of the London Basin, is accompanied by Tertiary phenomena equally interesting, and the occurrence of the Palæozoic platform at a small depth under the Chalk in the deep borings at Culford, Stutton, Harwich, and Weeley is, in this connexion, very significant.

Silurian or older rocks are separated from the Chalk at Culford, Stutton, and Weeley by a small thickness of Gault and Greensand only, while the rock met with in the Harwich boring, below 61 feet of the same beds, is believed by Professor W. W. Watts to have its closest

parallel in that underlying the fossiliferous Cambrian rocks at the Spinney Hills, Leicestershire.[1] Whatever classification may be adopted for the beds reached in the boring at Saffron Walden, in North-West Essex, it is clear that a good thickness of Jurassic rocks is present here, and the Palæozoic floor occurs at a greater depth than in Suffolk and the London area. Dr. Morley Davies, in discussing the contours of the ancient platform under the East of England,[2] has suggested that the Mesozoic Rocks below Saffron Walden probably lie in a trough in the Palæozoic floor on the north-east of, and complementary to, Professor Kendall's main Charnian axis through Bletchley, etc. Dr. Davies indicates also the subsequent rise of the floor under Suffolk (contour map, loc. cit., pl. xxxiv). Mr. H. A. Baker, F.G.S., in working at the problem of the movements which have affected the London Basin,[3] arrived independently at a similar conclusion, and was, the writer believes, the first actually to state the opinion that a secondary Charnian axis of unrest, parallel to Professor Kendall's main axis, occurred diagonally across Suffolk and the Thames estuary. Mr. Baker finds evidence of instability along this axis, in the Mesozoic rocks north-east of Dover, as well as in the Lower Cretaceous rocks of North-West Norfolk. He considers that its north-westerly prolongation coincides with the Louth–Willoughby anticline, a conclusion with which the writer cannot agree. It seems more probable that the irregularity of the Chalk in North-West Norfolk is connected with this anticline. Three anticlines of Charnian trend would thus lie in echelon.[4]

Some years ago the writer ascribed the change in strike of the Chalk at several points in the East of England to a possible bending over the knee of the Palæozoic platform beneath, and the coincidence of strong through-valleys and breaches in the Chalk escarpment at the point where the strike varied (points which might very well be termed the "points of deflexion") was commented upon. A few examples of these points of weakness, due to a kind of anticlinal arrangement of the Chalk, are the Wash Gap,[5] the Little Ouse–Waveney through-valley, revealed by the Chalk surface-contours, and probably post-Eocene and pre-Pliocene in age, the group of convergent valleys in South-East Suffolk, the Hitchin Gap, the Goring Gap, etc.

Somewhat later, in his Presidential Address to the Geological Society, 1913,[6] Dr. A. Strahan touched upon the same question in drawing attention to the Medway Gap at the change in strike of

[1] Quart. Journ. Geol. Soc., vol. lxviii, 1912, Proceedings, p. cviii.

[2] Dr. A. Morley Davies & J. Pringle, "On two deep Borings at Calvert Station (North Buckinghamshire) and on the Palæozoic Floor north of the Thames": Q.J.G.S., vol. lxix, p. 308, 1913.

[3] In manuscript, a copy of which was kindly sent to the writer in July, 1914.

[4] Since the above was written Mr. R. H. Rastall has informed me that there is evidence in Cambridgeshire of the north-easterly movement of the Charnian axis through Sandy. See also *Geology in the Field*, pt. i, p. 140, 1909.

[5] Professor W. G. Fearnsides, whom I have to thank for discussing several points with me, mentioned that Dr. J. E. Marr has drawn attention to the coincidence of the Wash Gap and the change in the strike of the Chalk, but Dr. Marr tells me he has not yet discussed the matter in print.

[6] Q.J.G.S., vol. lxix, Proceedings, p. lxxv, 1913.

the Gault. Upon a further consideration of the contours of the base of the Gault in this area, in the light of fresh records, Mr. Baker, in the MS. cited, concluded that a strong fault probably existed in the Cliffe area, the effect of which was to give the base of the Gault a downthrow of about 200 feet to the east. From evidence yielded by Tertiary beds he concluded there had been later movement along this fault, the prolongation of the line of which met the Medway Gap on the south and the south-north bend of the Thames on the north. As a result of plotting the Chalk surface-contours of the London Basin, the writer independently obtained evidence of the same fault-line, this time traced southwards from Billericay in Essex, approximately along the sudden bend of the Thames, by Cliffe to the Medway Gap. The sub-Eocene Chalk surface has received a down-throw of about 100 to 150 feet to the east.

This convergence of opinion from many workers engaged upon different problems appears to indicate that with the gradual accumulation of data the time is ripe for preliminary generalizations. The latter will serve to show the directions in which further work and information are required.

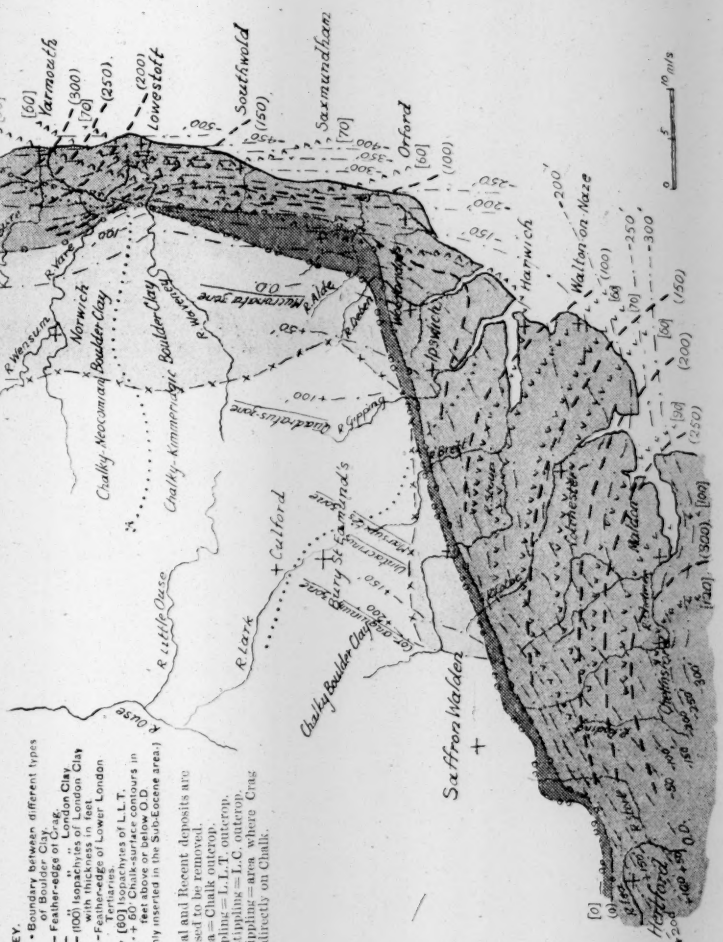
For the purpose of discussing any possible Tertiary movements about an unstable axis passing under South-East Suffolk, we must suppose the thick covering of Glacial Drift to be stripped off. The Crag must next be imagined as removed, and the form of the Eocene surface revealed. Finally, the Eocene beds must be stripped away, and the form of the Chalk surface and distribution of the zones realized. Incidentally, it may be pointed out that the change of strike of the Chalk at the Little Ouse–Waveney through-valley, from northerly in Suffolk to north-north-westerly in Norfolk, is hardly indicated by the 'solid' geology as shown upon the Geological Survey maps, although it is at once apparent by the behaviour of the Chalk zonal outcrops.

The Chalk zones change strike in South-East Suffolk also. The dip-slope of the Chilterns, south-west of the area, where the Chalk is covered by Eocene beds, consists of the *cor-anguinum* zone, the strike being generally north-eastwards. At Bishop's Stortford the Reading Beds rest upon Chalk of this zone, but in North-West Essex and South Suffolk, while the Chalk zonal outcrops swing round northwards, the Eocene beds maintain their strike, overstepping the various zones until they rest upon *mucronata* Chalk in East Suffolk. Dr. A. W. Rowe and Mr. G. E. Dibley tell me that the Chalk of Grays in South Essex is a high horizon in the *cor-anguinum* zone, and the presence of the *Marsupites* zone in North-East Kent is significant. The higher Chalk zones (above *cor-anguinum*) must therefore V up the London Basin under the Eocene beds, but their change of strike occurs south-west of that of the latter in East Anglia.[1]

The Chalk surface-contours change direction also in South-East Suffolk, but cut across the zones as indicated by the map, Fig. 1; their

[1] Messrs. H. J. Osborne White and L. Treacher have shown that near Newbury, i.e. on the opposite side of Professor Kendall's Charnian axis, *Marsupites* Chalk again occurs under Eocene beds, and farther westwards the *A. quadratus* zone just appears.

strike therefore changes in an area north-east of the zonal deflexion. The statement has been made that there is a thinning in the Lower and Middle Chalk over the possible axis in Suffolk. The writer is unable to find any evidence for such attenuation. There is, however, an important change in the gradient of the sub-Eocene Chalk surface in South-East Suffolk. This is indicated by the way in which the contours crowd up both south-west and north-east of the critical area. Some figures may be quoted: Beccles to Lowestoft, 55 feet to the mile; Halesworth to Southwold, 27 ft.; Ipswich to Walton-on-Naze, 11 ft.; Hadleigh to Weeley or Claeton, 17 ft.; Thaxted


KEY.
Boundary between different types of Boulder Clay.
Feather-edge of Crag.
Feather-edge of London Clay.
(100) Isopachytes of London Clay with thickness in feet.
Feather-edge of Lower London Tertiaries.
(50) Isopachytes of L.L.T.
Chalk surface contours in feet above or below O.D. (only inserted in the Sub-Eocene area.)
The Glacial and Recent deposits are supposed to be removed.
White area = Chalk outcrop.
Dark stippling = L.L.T. outcrop.
Medium stippling = L.C. outcrop.
Light stippling = area where Crag rests directly on Chalk.
Yarmouth
Lowestoft
Southwold
Saxmundham
Orford
Harwich
Walton on Naze
Ipswich
Norwich
Chalky Boulder Clay
Chalky-Kimmeridgian Boulder Clay
Chalky Neocomian Boulder Clay
Saffron Walden
Hadleigh
Colchester
Maldon
Chelmsford
Brentwood
Romford
Dartford
Gravesend
Sheerness
Whitstable
Canterbury
Ashford
Folkestone
Dover
Deal
Sandwich
Ramsgate
Margate
Herne Bay
Faversham
Sittingbourne
Rochester
Maidstone
Tonbridge
Tunbridge Wells
Hastings
Rye
Winchelsea
Battle
Eastbourne
Brighton
Lewes
Newhaven
Seaford
Worthing
Littlehampton
Bognor
Chichester
Selsey Bill
Portsmouth
Southampton
Lymington
Christchurch
Bournemouth
Swanage
Weymouth
Portland Bill
Dorchester
Bridport
Lyme Regis
Axminster
Honiton
Sidmouth
Exmouth
Exeter
Dawlish
Teignmouth
Newton Abbot
Torquay
Paignton
Brixham
Dartmouth
Kingsbridge
Salcombe
Plymouth
Tavistock
Launceston
Bude
Boscastle
Tintagel
Camelford
Wadebridge
Padstow
Newquay
Redruth
Camborne
Penzance
St. Ives
Hayle
Helston
Falmouth
Truro
St. Austell
Fowey
Looe
Liskeard
Saltash
Torpoint
Millbrook
Cawsand
Rame Head
Eddystone
Start Point
Prawle Point
Bolt Tail
Bigbury Bay
Burgh Island
Salcombe
Kingsbridge
Dartmouth
Brixham
Torquay
Paignton
Teignmouth
Dawlish
Exmouth
Sidmouth
Beer
Seaton
Lyme Regis
Bridport
Weymouth
Portland Bill
Swanage
Bournemouth
Christchurch
Lymington
Southampton
Portsmouth
Selsey Bill
Chichester
Bognor
Littlehampton
Worthing
Seaford
Newhaven
Lewes
Brighton
Eastbourne
Battle
Rye
Hastings
Tunbridge Wells
Tonbridge
Maidstone
Rochester
Chatham
Gillingham
Sittingbourne
Faversham
Herne Bay
Margate
Ramsgate
Sandwich
Deal
Dover
Folkestone
Ashford
Canterbury
Whitstable
Sheerness
Gravesend
Dartford
Romford
Brentwood
Chelmsford
Maldon
Colchester
Winchelsea
Harwich
Walton on Naze
Ipswich
Orford
Saxmundham
Southwold
Lowestoft
Yarmouth
Norwich
Saffron Walden
Hadleigh
Chalky Boulder Clay
Chalky-Kimmeridgian Boulder Clay
Chalky Neocomian Boulder Clay
R. Ouse
R. Little Ouse
R. Stour
R. Waveney
R. Yare
R. Bure
R. Wensum
R. Glaven
R. Blyth
R. Alde
R. Deben
R. Orwell
R. Stour
R. Colne
R. Roach
R. Crouch
R. Blackwater
R. Chelmer
R. Lee
R. Medway
R. Darent
R. Cray
R. Ravensbourne
R. Wandle
R. Mole
R. Arun
R. Adur
R. Ouse
R. Cuckmere
R. Rother
R. Brede
R. Tillingham
R. Dengie
R. Crouch
R. Roach
R. Colne
R. Stour
R. Orwell
R. Deben
R. Alde
R. Blyth
R. Yare
R. Waveney
R. Wensum
R. Glaven
R. Bure

to Chelmsford, 27 ft.; near Bishop's Stortford to Chipping Ongar, 36 to 44 ft. (On account of the small scale of the map a few local irregularities in the surface-contours have been smoothed out. The results are still reasonably accurate.) See Fig. 1, p. 201.

The north-westerly limits of the Lower London Tertiaries (the Thanet Beds and Reading Beds are not differentiated) and London Clay are also shown upon the map. Considering the former beds first, it will be seen that they overstep the Chalk zones and surface contours, their point of deflexion occurring near the Rivers Deben and Alde, again north-east of the change of strike last considered, namely, that of the Chalk surface-contours. Their thickness, as given by field evidence and well-borings, etc., has been plotted on the map and approximate isopachytes (lines joining points at which the thickness of the beds is the same) drawn. An interesting result follows in consequence of the thickening of these beds in both directions from the critical area. Owing to the thinning off of the beds by erosion to a feather-edge on the north-west,[1] these isopachytes are not normal to the strike, but take the form of curves thrown back along the feather-edge, but always convex to the critical area (except in this area itself, where, like the 50-feet isopachyte, they are convex to the south-east). Although the Thanet Beds are thinner in the neighbourhood of the Gipping Valley than elsewhere in the whole district, they show no evidence of shallow-water or shore-line conditions, as do the similar beds in the Sudbury area. Near their surface, however, they appear to yield evidence of planation, and contain lenticles of large wind-polished grains and small pebbles of flint and quartz. It would thus appear that the movement of uplift which spaced out the Chalk surface-contours was in abeyance in Thanetian times, but reasserted itself at their close. The thickening of the Thanet Beds north-eastwards and south-westwards would be accounted for by greater denudation over the central area.

The Reading Beds, which also thicken on each side of the point of deflexion, consist in the central area of sandy beds with subordinate lenticles of plastic clay. Both on the north-east and south-west, as far as we can rely upon records of borings, etc., they appear to consist of greater thicknesses of mottled clays with subordinate beds of sand. In view of the widespread shallowing in Reading Bed times, a movement which culminated all over the district in the formation of the bed of rounded black flint pebbles (variously referred to the Oldhaven Beds and to the basement-beds of the London Clay), care has to be exercised not to force the evidence.

Widespread and steady submergence took place during the deposition of the London Clay over the area. The great thicknesses of the deposit recorded in well borings comparatively near to the feather-edge point to sedimentation under isostatic conditions. The northerly and westerly limit of the London Clay is indicated upon the map, and it is to be observed that the change of strike occurs north-eastwards of that of the Lower London Tertiaries. The boundary of the former deposit retreats from that of the latter in the neighbourhood

[1] It should be noted that this feather-edge constitutes the zero isopachyte.

of Saxmundham, but overlap occurs farther northwards, and in Norfolk the London Clay rests directly upon the Chalk. The same point is brought out by the distribution of the isopachytes of the bed. Like those of the Lower London Tertiaries, they are convex to a central axis (now north-east of that of the isopachytes of the Reading Beds), but their gradient is much steeper, and their form therefore better marked. It remains only to say that the London Clay near the point of deflexion does not reveal more evidence of shore action than that on the north and west. The thinning of the bed is due to erosion, and the surface is inclined to be irregular. It seems probable that slight uplift was taking place in the central area during deposition, and sagging and sedimentation on each side of it, but it was not until post-London Clay times that the movement became very marked.

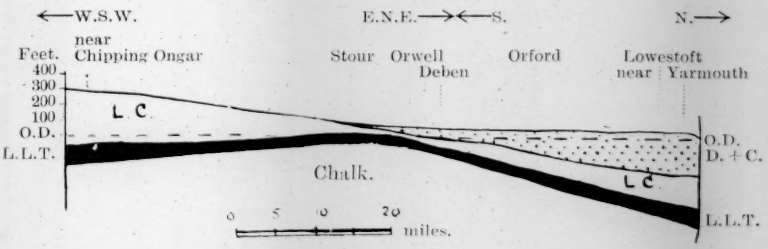


FIG. 2.—Section (to scale) across the axis of unrest in South-East Suffolk. The line of section is taken parallel to the Eocene boundaries. L.C. = London Clay ; D. + C. = Drift and Crag ; L.L.T. = Lower London Tertiaries ; O.D. = Ordnance datum.

The unconformity of the Crag (considered as a whole) upon the Chalk and older Tertiary beds is worthy of note. At Mundesley and other places in North-East Norfolk, it rests upon the *lunata* zone (to retain an old name) ; in the neighbourhood of Norwich, upon the *mucronata* zone ; in South Norfolk (Tharston, etc.), upon a very low horizon of the latter zone ; and in East Suffolk possibly upon a high horizon of *quadratus* Chalk. In South-East Suffolk, however, the Crag boundary (see Fig. 1) osculates with that of the Eocene beds, or even passes a little way within it. In this area the Pliocene beds are seen resting upon Thanet Beds, Reading Beds, and, most frequently, London Clay, but not upon the Chalk. On passing into West Suffolk we find the Crag again resting upon bare Chalk of the *cor-anguinum* zone, e.g. at Stoke-by-Clare.

One of two things has therefore happened. Either the Crag boundary was once more or less parallel to that of the Eocene beds, and retreated as a result of erosion to its present position in pre-Upper Glacial times (pre-Glacial of the area under consideration), or the Crag was never deposited over part of the critical area. The latter case would yield evidence of the anticlinal form of the central area in Pliocene times ; the former, of differential uplift in the area, resulting in greater erosion of the Crag, since the general level of the country in South-East Suffolk is as high as on the north-east and south-west, and

the broad V in the Crag boundary is not due to a valley and geometry. Both considerations lead to the same conclusion of instability over the central area.

The Red Crag is believed to have been deposited in a number of land-locked bays which were being gradually forced northward by a series of earth-ripples, resulting in a general uplift on the south and subsidence on the north.[1] It may be merely coincidence that the Crag between the Orwell and the Stour shows evidence of much oscillatory movement; abundant pebbles, an impoverished fauna, and rolled and broken shell-fragments are characteristic.[2] The Crag deposits of Walton and Oakley on the one hand, and of Sutton, Butley, etc., on the other, while being drift-bedded, are richer in species, contain tiny and fragile shells, and show less evidence of disturbing conditions. It should also be remarked that the Boxstone Bed at the base of the Crags is confined to the central area.

The bearing of the form of the river-systems (which probably had their inception in Miocene times) upon the question will be discussed later.

The boundary between the two very different types of Upper Boulder-clay (Great Chalky Boulder-clay of S. V. Wood, jun.) in Suffolk has been inserted on the Map. This is adapted from Mr. F. W. Harmer's maps, with slight corrections, as a result of detailed mapping, by the writer.[3] We know that the general topography of Suffolk and Northern Essex was, in pre-Glacial times, much as it is now, and exercised a strong influence upon the ice-movements. This appears to be indicated by the boundary between the Chalky-Neocomian Boulder-clay and the Chalky-Kimmeridgic Boulder-clay in the lower part of the Waveney Valley, the latter occurring at Somerleyton, Burgh Castle, etc., and the former at Haddiscoe, etc.[4] The line of demarcation between the Chalky-Kimmeridgic Boulder-clay and the Chalky (or Chalky-Oxfordic) Boulder-clay in Suffolk is equally abrupt, and its position noteworthy, even if meaningless in the present connexion.

One of the best methods of registering secular movements taking place at the present day is provided by the behaviour of rivers. The following facts were not sought, but accumulated in the course of work upon the evolution of several East Anglian rivers.

Gradient-curves of all the East Anglian rivers have been plotted, and are seen to be of the usual logarithmic form. Rejuvenation, however, is revealed up to about the 50 ft. contour in the case of the Gipping, Stour, and Colne, by the introduction of a new and smaller logarithmic curve upon the lower portion of the old curve. In the case of the Chelmer and Deben, this rejuvenation extends to about the 25 ft. contour; it is hardly shown by the Alde, and does

[1] Mr. F. W. Harmer in numerous papers.

[2] See the writer, Proc. Geol. Assoc., vol. xxiv, p. 330, 1913.

[3] F. W. Harmer, *Geology in the Field*, pt. i, pl. iii, 1909; Trans. Norfolk and Norwich Nat. Soc., vol. ix, plate at p. 132, 1910; see also Proc. Geol. Assoc., vol. xxv, pl. xxiv, 1914.

[4] F. W. Harmer, loc. cit., 1910, p. 119.

not appear to be present in the Thames, Lea, Roding, Waveney, Norfolk rivers, and Wash rivers. Such rejuvenation may be due to many causes, but in the present instance most may be eliminated. The case is simplified by the fact that the whole district was subjected in post-Glacial times to a depression which turned the lower portions of the valleys into estuaries and caused them to be partly silted up. This depression, of at least 25 feet in the critical area, and considered to be 60 to 80 feet over the area from the Thames to the Wash, etc., by Mr. Clement Reid, successfully arrested the development of the rivers, the valleys of which were already overloaded with glacial débris.[1] Thus no release from damming has occurred; also rainfall has diminished, and there has been no increase in power or drainage area of the rivers, since late-Glacial times. Such capture as appears to have taken place is related only to the pre-Pliocene grain of the country and is certainly pre-Upper Glacial.[2] Moreover, the Colne is a beheaded stream, and yet shows the same amount of rejuvenation as the Stour, which has robbed it. The Gipping, with similar rejuvenation, is purely a dip stream. The Deben and Chelmer have largely increased their drainage area by piracy, but exhibit less change in gradient. It is submitted, therefore, that a strong probability exists that the rejuvenation is due to uplift.[3] When the results are plotted diagrammatically, Fig. 3 is obtained, and the evidence points to differential uplift in the area previously proved to be unstable.

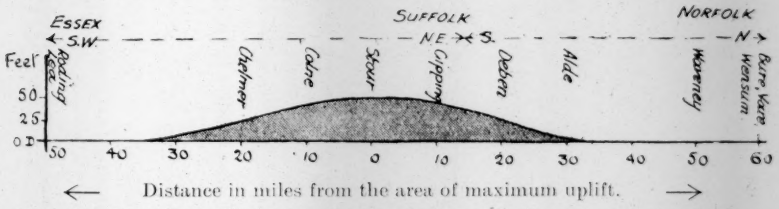


FIG. 3.—Diagrammatic representation of the variations in amount of the rejuvenation of East Anglian rivers. The heights to which rejuvenescence occurs are marked off vertically.

Summarizing, we may say that the outstanding feature is the manner in which the points of deflexion where change of strike occurs, and the axes producing them, moved north-eastwards. The Chalk zones are the first to change strike, then the sub-Eocene surface contours, next the Lower London Tertiaries, and finally the London Clay. The ripple then seems to have reached its farthest extent north-eastwards, and was subsequently reflected from the area under which the Palæozoic floor rises.

The river capture which has taken place has curiously had the effect in all important cases of throwing the drainage in towards the

[1] It was possibly this depression which buried the Neolithic skeleton and deposits found below tide-level near Walton-on-Naze by Mr. Hazzledine Warren.

[2] Q.J.G.S., vol. lxix, p. 612, etc., 1913.

[3] Rejuvenation up to the 50 ft. contour does not mean an uplift of 50 feet. A much smaller elevation would yield the result.

critical area (see Map, Fig. 1, p. 201). If such capture took place in Miocene times, it would appear to have been due to the hollow complementary to the ripple-crest which was at that time farther north-eastwards. Although the region was affected by widespread movements in Pliocene times, the crest may have tended to return south-westwards again as indicated first by the Crag outcrop and later (and farther south-westwards) by the rejuvenation due to uplift.

What was the impelling force driving the ripple so persistently north-eastwards, where did it originate, what are its effects outside this area, and what is the meaning of the rebound? These are theoretical considerations upon which it is better perhaps not to speculate at present, but which may open up fresh questions and lead to further investigation and accumulation of evidence.

Finally, it should be stated that the problem of attempting to prove the existence of an unstable axis was never embarked upon. The facts obtained in the course of working out other problems on each of the East Anglian deposits gradually fell into line.

III.—Tektite from British Borneo.

By Dr. F. P. Mueller, Basle (Switzerland).

It is well known that in various regions of Europe, Asia, and Australia dark pieces of glass are found which, in view of their peculiar shape and sculpturing, have attracted the attention of observers for a good many years. The name of *obsidianite* was given to these objects by R. H. Walcott. It expresses their resemblance in petrographic nature to obsidian.

Obsidianites are found in widely separated regions. It is evident from their physical and chemical properties that they belong to one petrographic class. However much they resemble one another there are points characterizing the specimens of each region. For this reason F. E. Suess has classified the obsidianites according to the main places of their occurrence, as *Moldavites*, *Billitonites*, *Australites*, and *Queenstownites*. In this view the origin of obsidianites is considered as a cosmic one, and excludes any comparison between them and obsidian; as an alternative the same author has chosen the name of *tektite* (τήκτος, molten), which he thinks is less open to objection.

The origin of tektites has been dealt with in numerous publications. It is their occurrence upon or in later deposits remote from recent volcanoes and manufactories, and their shape and sculpturing, that have been considered as the result of their cosmic source. Many doubts have been expressed as to these points. The extreme discordance between the petrographic characters of meteorites and tektites, chemically belonging each to the opposite ends of the rock series, was supposed to prove the impossibility of a meteoric origin for the tektites. Yet it is evident from a study of the analyses that there is no agreement between the chemical composition of tektites and of any similar known terrestrial rocks. It will therefore be hardly possible to think of any other than a cosmic origin for them.

The bibliography of tektites consists of numerous articles and monographs. Full lists are given in the following publications up to date of their appearance :—

1898. R. H. Walcott, Proc. Roy. Soc. Victoria, vol. xi, pp. 51–2.
1900. F. E. Suess, Jahrbuch K.K. geol. Reichsanstalt, vol. l, pp. 196–200.
1914. F. E. Suess, Mitteilungen Geol. Ges. Wien, vol. vii, pp. 54–6.

Attention must be drawn to the last of these three monographs. It gives full information on the chemical properties, and deals with all doubts that have been expressed on the origin of tektites. Further, it contains a description of a new kind of tektite, called Queenstownite.

It is the purpose of the present paper to describe a find of tektite from British Borneo, and specially to refer to those points which in view of the importance of this new occurrence are considered necessary.

The Tektites of the Sunda Archipelago.

The occurrences of tektites in the Archipelago, so far as known up to date, fall within an area that extends from the south-eastern corner of Borneo in a north-western direction to the southern portion of the Malay Peninsula, including the northernmost point of Java and the islands of Billiton and Great Natuna (Fig. 1).

The specimens from the Malay Archipelago are comparatively few in number, far fewer than the European and Australian tektites. Tropical vegetation and preponderance of sea within the above area might account for this.

Only in places where in consequence of mining operations the superficial deposits have been carefully examined, have a greater number of specimens been found, such as on Billiton Island and in the Malay Peninsula. Owing to the abundant occurrence at Billiton, the name of *Billitonite* has been assigned to all tektites from Malaysia.

It appears that the first Billitonite was found at Pleihari, in the south-east corner of Borneo, by S. Mueller, about the year 1836. A second specimen is known from the neighbourhood of one of the two Riam rivers, north of Pleihari. Two specimens are known from Mt. Muria, in Java, but only one appears to be an undoubted tektite. In 1879 P. van Dijk first described the Billiton occurrences, which were fully treated by R. D. M. Verbeek in 1897. In 1898 two specimens were recorded by P. G. Krause from Great Natuna. In 1909 a number of occurrences from the Federated Malay States was dealt with in the Geological Magazine by Mr. J. B. Scrivenor (p. 411).

The Tektites from British Borneo.

In February, 1913, the writer found four specimens of tektite in close proximity to Tutong Station, south-west of Brunei town. They were lying in a track, leading northward, and somewhat cut back into a small hill just behind the Chinese shops of the village. Apparently the stones were washed out of a white quartz sand, from a depth of one to two feet below the surface. This sand is part of a deposit that forms a well-marked terrace about 40 feet above sea-level along the coast of Brunei, especially near Yerudong, north-east of Tutong.

The sand deposit certainly does not belong to the present epoch, but is at least of diluvial age. It is evident, therefore, that the tektites, like those of Billiton and of the Federated Malay States, geologically speaking are also of diluvial age.

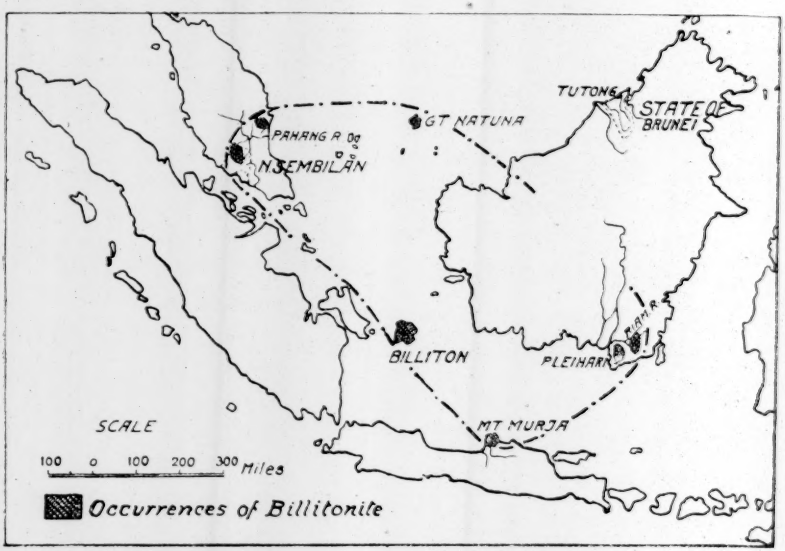


FIG. 1.—Map showing the area in which is included all known occurrences of Billitonite in the Malay Archipelago (dot and dash line).

The general characters of the Brunei specimens are shown in the following table (Table I):—

TABLE I.

No. of the Specimens	1	2	3	4
Size (mm.) . .	30/23/15	Diameter about 13	20/14/13	10/8/15
Weight (gr.) . .	11·72	5·37	5·87	0·5
Shape . . .	triangular	spherical	egg-shaped	triangular

The four specimens have the brilliant black lustre which is commonly characteristic of tektites. They are completely scored with very small marks, which makes their surface appear as if fine-grained. Closer examination shows the hemispherical moon-like hollows, often incompletely developed, which so commonly occur on Billitonites. Nos. 1 and 4 show a few deep, elongated pittings slightly wrinkled, rather smooth inside.

Physical properties.—The specific gravity is G = 2·457. The hardness is H = 6. The colour is dark-green brown. The index of refraction, measured on two optic prisms prepared from No. 2, was found $n = 1·5097$ (Na). All sections revealed without aid of the microscope a fluidal structure.

Microscopic examination proved the specimens to be an almost pure glass. A very few, small, scattered vesicles were noted, while by aid of the strongest enlargement only a few indeterminable mineral particles were observed. Comparing the physical properties with those of Billitonites it is evident that they are almost identical.

Chemical composition.—The following analysis of a Brunei tektite was made by Dr. Hinden in Basle. In the first column is shown the percentage of each oxide, and in the second is given the molecular proportion.

TABLE II.

SiO_2 . . .	70·90	118·17
Al_2O_3 . . .	13·50	13·24
Fe_2O_3 . . .	0·32	0·20
Fe O . . .	5·47	7·60
Ca O . . .	2·35	4·20
Mg O . . .	2·45	6·12
Na_2O . . .	1·46	2·35
K_2O . . .	2·17	2·31
TiO_2 (estimated) :	1·00 (*ca.*)	1·25 (*ca.*)
Mn O . . .	trace	—
	99·62	155·44

The accompanying diagram (Fig. 2), p. 210, has been drawn in order to compare the Brunei tektite with the Billitonites and the best corresponding Australites. It shows the molecular proportions of the principal oxides plotted as ordinates, those of the silica taken as abscissæ of five analyses of Australites (Nos. I, IV, V, VI, VIII), two of Billitonites (Nos. 9, 10), and one of the Brunei tektite (No. **a**). The diagram is a modification of the basic portion of F. E. Suess' Table iii, 1914. The roman numerals correspond with those by which H. S. Summers (Proc. Roy. Soc. Victoria, vol. xxi, 1908) has marked the analyses of the Australites. The Arabic numerals are the numbers given in the same analyses as well as the analyses of the Billitonites by F. E. Suess, 1914, pp. 86–7 (see Table III, p. 211).

The examination of the diagram shows that the Australites and the Billitonites form two well-marked groups, their chemical variation being different in character. F. E. Suess (1914, p. 98) states as characteristic of the Billitonites the small percentage of alumina and the high percentage of alkalies. The rapid decrease of iron, magnesia, and lime is equally striking, while for the Australites these substances maintain an almost uniform position, diminishing very slightly only towards the acidic end of the series.

The Brunei tektite, as expressed by the diagram, though containing an almost equal quantity of silica as the Billitonites, shows little

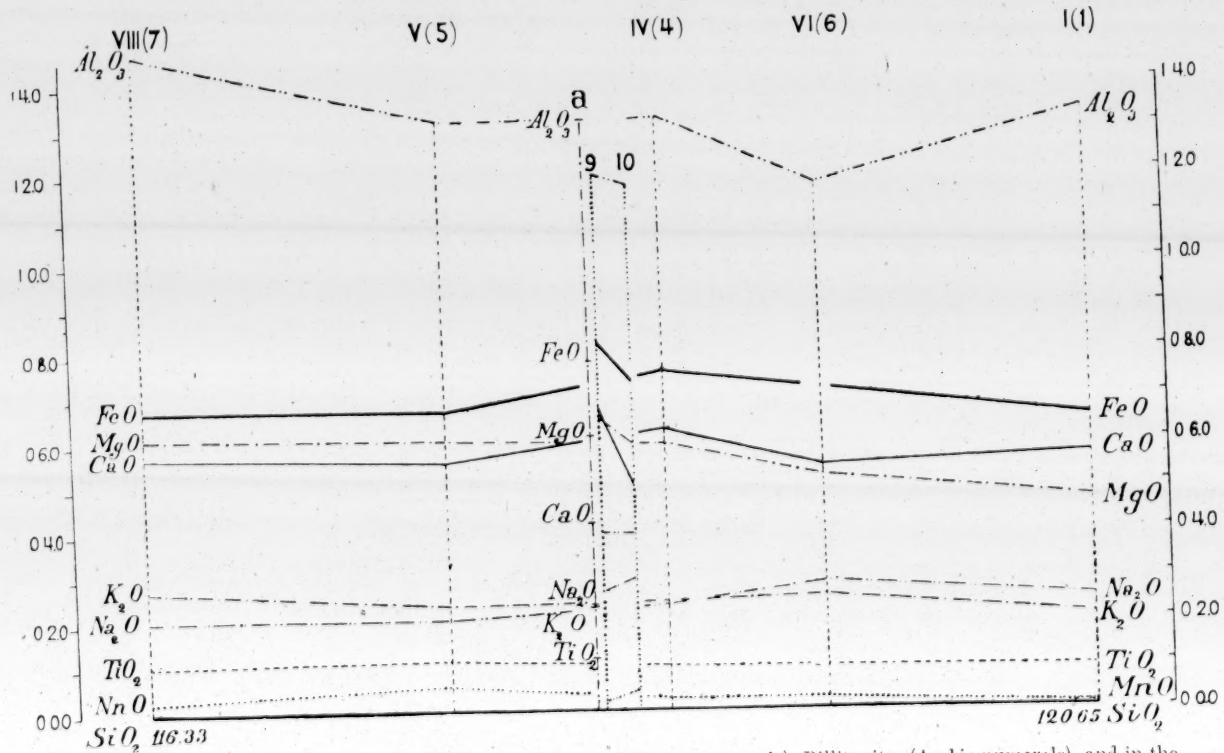


FIG. 2.—Diagram to show molecular variation in Australites (Roman numerals), Billitonites (Arabic numerals), and in the Brunei tektite (a).

agreement with the above characteristics and those of the latter group. Its alumina is as high as that of the Australites. The alkalies are low, but equally correspond with the position of the alkalies of the Australites. There is also more agreement between the amount of iron and magnesia of the Australites and the Brunei tektite than between the latter and the Billitonites. Lime is irregular and comparatively low in position.

It is known that the quotient from the sum of iron and magnesia divided by the sum of the alkalies, as well as the ratios of lime, potash and soda are the evidences that distinguish the tektites from all terrestrial rocks. Besides this, moreover, they also characterize each group of the tektites, as is clearly shown in the following table (Table III). It is evident from the diagram and also from this table that the Brunei tektites do not correspond chemically with the group of the Billitonites, but that there is much resemblance between them and the Australites.

TABLE III.

Number of the Analyses.	$\frac{FeO + MgO}{Na_2O + K_2O}$	$CaO : Na_2O : K_2O$
Australites . . . I	2·5	6 : 2 : 2
IV	2·8	6 : 3 : 2
V	2·9	5 : 2 : 2
VI	2·7	5 : 2 : 3
VIII	2·6	6 : 2 : 2
Billitonites . . . 9	1·9	5 : 3 : 4
10	2·2	7 : 3 : 4
Brunei tektites . . **a**	2·9	4 : 2 : 2

Conclusions.—The tektites from Brunei in British Borneo are, geologically speaking, most likely of diluvial age. Their shape and sculpturing show nothing peculiar. Their physical properties correspond with those of Billitonites. In their chemical composition there is much resemblance between them and the Australites.

IV.—Studies in Edrioasteroidea, VII. Morphology and Bionomics of the Edrioasteridae.

By F. A. Bather, M.A., D.Sc., F.R.S.

Published by permission of the Trustees of the British Museum.

THERE have now been described all the known members of the Edrioasteridae and the very similar genus *Steganoblastus*, as well as a genus apparently connected with the Agelacrinidae but presenting some remarkable features, namely *Pyrgocystis*. It is proposed in this and the following Study to deal particularly with

the Edrioasterid organization, first considering what the known facts of skeletal structure imply as to the general anatomy and mode of life, secondly comparing the structure with that of other echinoderms, especially the Asteroidea. Although it may be necessary to refer to various facts that fall to be dealt with in future Studies, still the present seems a convenient opportunity for this general discussion, because of the recent publication by Mr. W. K. Spencer of the introduction to "A Monograph of the British Palæozoic Asterozoa" (Feb., 1914, Palæontogr. Soc. vol. for 1913), by Dr. J. F. Gemmill of his highly important memoirs on the starfishes *Solaster endeca* (1911, Proc. R. Phys. Soc. Edinburgh, vol. 18, pp. 174–91; and Feb., 1912, Trans. Zool. Soc. London, vol. 20, pp. 1–71, pls. i–v) and *Asterias rubens* (Oct., 1914, Phil. Trans., ser. B., vol. 205, pp. 213–94, pls. xviii–xxiv, and March, 1915, Proc. Zool. Soc. London, pp. 1–19, pls. i–iii), and by Dr. A. F. Foerste of some suggestive "Notes on Agelacrinidæ" (Sept., 1914, Bull. Sci. Lab. Denison Univ., vol. 17, pp. 399–486, pls. i–vi).

First, then, as to the internal organization and mode of life of the Edrioasteridae. It is clear from the position of the three openings—mouth, anus, and water-pore—on one face, that that face was directed upwards as in normal Pelmatozoa. Apart from that argument, the general resemblance of *Edrioaster* and *Dinocystis* to the undoubtedly sessile Agelacrinidae clearly indicates a similar position with regard to the sea-floor, even though the edrioasterids in question may not have been permanently attached. *Steganoblastus* obviously was fixed by a stem of ordinary pelmatozoan character, and by the mechanical stresses thus set up its theca has been modified so as to present a remarkable resemblance to that of a blastoid. How this stem originated is suggested by the parallel history of *Pyrgocystis*, in which we seem to trace the gradual elevation of the loosely and irregularly plated thecal wall, as seen in *Cystaster*, through the low turret of *P. sardesoni*, to the elongate stem-like turret of *P. grayae* and the more regularly plated turret of *P. ansticei* and *P. sulcata*.

Another criterion of Pelmatozoa is: "Food brought to the mouth by a subvective system of ciliated grooves, radiating from the mouth." The evidence for this in all Edrioasteroidea is the presence of radiating grooves protected by cover-plates, which plates are particularly well developed in Edrioasteridae and *Steganoblastus*, and apparently immovable over the mouth-region.

The only pelmatozoan character not yet mentioned is the presence of "an aborally placed motor nerve-centre". The presence of such a centre in *Steganoblastus* at any rate may be inferred from the stem with its lumen (Study V, 1914, p. 202) and from the axial folds similar to those which in many crinoids are known to have afforded passage for the nerves from that centre (Study V, p. 197). The possible relation of the lobes seen on the adapical face of *Edrioaster* to a chambered organ, such as that with which this nerve centre is connected in the crinoids, was discussed in Study II (1900, p. 202). It is, however, scarcely necessary to point out that a sessile or almost sessile form such as *Edrioaster*, without stem and without movable arms, had little or no need for such a motor nerve-centre. If we

suppose the Edrioasteridae to be descended from forms with a more definite organ of attachment and with a moderately developed aboral nerve-system, we shall none the less expect to find that system considerably atrophied and leaving but slight traces. If, on the other hand, we suppose that the Edrioasteridae received their aboral nerve-system directly from the supposed anterior nerve-ganglion of some pre-echinodermal ancestor, *Dipleurula* or other, then again this will scarcely have been modified far in the direction of a motor centre. The same remark applies to any imaginable derivation of the Edrioasteridae from some echinoderm other than a Pelmatozoön, say a primitive Asterozoön.

The proof that the Edrioasteridae are Pelmatozoa in the full signification of that name has been laboured because the striking characteristic of this Family, more than of any other Edrioasteroidea, is just that strange resemblance to Asteroidea which suggested the second component of the Class name, and which will be fully discussed in the next Study.

Let us now consider more closely the Form and its relation to Fixation.

Edrioaster, *Lebetodiscus*, and *Dinocystis* have their rays curved like those of *Agelacrinus*, *Lepidodiscus*, and similar Agelacrinidae. This ensures a more or less circular outline of the theca or at all events checks any tendency to a star shape. That this curvature is secondary is an obvious conclusion from a comparison with the Agelacrinidae, from the facts of individual growth (Study IV, 1914, pp. 120, 121), and from the existence of the straight-rayed *Steganoblastus*. Further, the oldest known Edrioasteroid, *Stromatocystis* from the Middle Cambrian, has straight rays. This last form is pentagonal, with a tendency to be stellate; but it cannot therefore be inferred that its as yet unknown ancestor was more stellate. The assumption of a pentagonal or star shape is a consequence of the straight outgrowth of the food-grooves. All that we know of the evolution of those structures in the earlier Pelmatozoa indicates that, in race-history as in individual growth, they stretched gradually outwards from the mouth, and by degrees impressed a radiate symmetry on every part of the theca as well as on the internal organs. *Stromatocystis*, as will appear in a subsequent Study, affords no evidence of descent from an ancestor in which the radiate symmetry was more strongly marked than in itself. On the contrary, for this Cambrian genus, as for all the Ordovician Edrioasteroids, the natural inference is that they are descended from a simple sack-like, irregularly plated pelmatozoön with no more than the beginnings of radiation seen in its food-grooves, which at first were but three in number. (See Treatise on Zoology, 1900, p. 11; Study I, 1898, p. 545; Study V, 1914, p. 201; and A. Foerste, 1914, op. cit., p. 412.)

It is generally admitted that radiate symmetry of this kind can only have arisen in a fixed form, and that in the case of Pelmatozoa the fixation must have been by the apical end. Such fixation was retained, or perhaps emphasized, in *Cyathocystis* and *Steganoblastus*. *Stromatocystis*, however, the only Edrioasteroid as yet known from

Cambrian rocks, was certainly not fixed, and can have had at most a loose and variable attachment. Between these extremes lie all the forms of attachment found in the Edrioasteroidea, differing from genus to genus, and even from species to species, according to the needs of the environment. Thus, evidence has been adduced to show that, in spite of Jaekel's contrary opinion, *Edrioaster* and *Dinocystis* were not actually fixed (Study II, 1900, p. 200; Study IV, 1914, p. 169). Direct evidence is wanting in the case of *Dinocystis*, but the indirect proof is the same as for *Edrioaster*, namely, that the fossils are never found resting on any hard surface, but have the apical face covered with shale or sand, which cannot have afforded a firm basis of attachment. It is by parity of reasoning that *Pyrgocystis grayae* and its Wenlockian successors are supposed to have been not fixed but inserted in a sea-floor of similar loose consistency, although *P. sardesoni*, in its firmer surroundings, seems to have been fixed.

The general situation of such Agelacrinidae as '*Agelacrinus*' sensu lato, *Hemicystis*, and *Streptaster*, upon the smooth hard surfaces of shells and similar objects, suggests a permanent fixation, and I can recall no very clear evidence to the contrary. Dr. Foerste, however, says (1914, op. cit., p. 407):° "In all of the Ordovician species referred to *Agelacrinus* or *Lepidodiscus*, the animal evidently was capable of attaching itself to various objects for support, although this attachment was not permanent, and occasional specimens are found unattached." The nature of this temporary attachment is imagined by Dr. Foerste to have been essentially the same as that suggested by me for *Edrioaster* and *Dinocystis*. As explained in Study II (1900, p. 202), it is supposed that this was effected by an action comparable to that of a limpet or a sea-anemone or of any mechanical sucker. In all the species of Edrioasteridae the necessary elements of the theca were present, namely an apical concavity, a rigid frame, and a central area of flexible integument. We know, it is true, nothing of the muscles within the thecal cavity that may have raised up this central integument, but the radial muscles of the flexible-tested sea-urchin *Asthenosoma* indicate how readily the necessary muscles may have been developed. Another mechanism, however, may be conceived. If, as here maintained, the pores between the floor-plates of the subvective grooves led from podia fringing the grooves to ampullae within the thecal cavity, then the distension of the ampullae by influx of water through the hydropore, or by retraction of the podia, would exert hydraulic pressure on the walls of the theca and their flexible portions would be inflated. If now, the ampullae were contracted and all their contained fluid forced into the podia or even out through the hydropore, then the flexible parts of the thecal wall would necessarily be drawn inwards. Thus, if the thecal margin were resting on a sandy bottom, a vacuum would be created, with consequent sucker action.

In so far as this latter hypothesis helps to account for the presence of pores in the free Edrioasteridae, just so far does it fail to harmonize with their presence in the fixed *Steganoblastus* with its more rigid theca. Moreover, if the Agelacrinidae were attached by sucker

action, their lack of pores prevents the extension of the hypothesis to them. It is, however, not only pores that are lacking, but also a plated apical integument, as may readily be proved by dissection or grinding either from above or from below, and by thin transverse sections (see further, W. K. Spencer, 1904, Proc. Roy. Soc., vol. 74, p. 43, l. 9, where for 'ventral' read 'dorsal'; also Foerste, 1914, op. cit., p. 409, § 13). Not that the absence of calcification would be the smallest bar to sucker-action, or to locomotion,[1] but it suggests that the animal rarely if ever relinquished its attachment.

The lobes of the flexible integument round the apical pole have been discussed more than once (Study II, 1900, p. 201; Study IV, 1914, p. 169). They have been found in all specimens of *Edrioaster* available for the prolonged preparation usually required; but this area is obscured in *Lebetodiscus*, and in *Dinocystis* all that can be traced is an occasional suggestion of an evagination (see text-fig. on p. 135, vol. 6, 1899) and foldings indicative of a stretched membrane (Study I, 1898, p. 546).

The number of lobes is five in the holotype of *Edrioaster buchianus*. In the specimens of *E. bigsbyi* the lobation is not so regular, but there are indications of the same pentamerism. Within the rounded margins of the lobes the integument is depressed, that is to say, withdrawn towards the interior of the theca. The lobes in *E. buchianus* were described as interradial, but in a form where the subvective grooves coil round from one radius into another, it is very difficult to decide upon the correct orientation of the apical face.

Whatever these lobes may mean, it is interesting to observe precisely similar structures, apparently with similar interradial position, figured by Jaekel in his *Thecocystis sacculus* (1899, pl. i, fig. 1 *b*) and described as an "Ansatzfläche" or "Anwachsungsfläche". In *Stromatocystis* also there is a pentagonal swelling with central depression round the apical pole, but the angles of the pentagon are prolonged in a distinctly radial direction.

This evagination may have had something to do with temporary fixation, but it does not reach as low down as the thecal periphery, and this function does not explain its quinquelobate structure. The only conclusions that can safely be drawn from the facts are that the shape indicates some rather firm internal organ or organs with quinque-radiate plan but without calcified skeleton. Beyond this all is pure speculation.

(*To be concluded in our next Number.*)

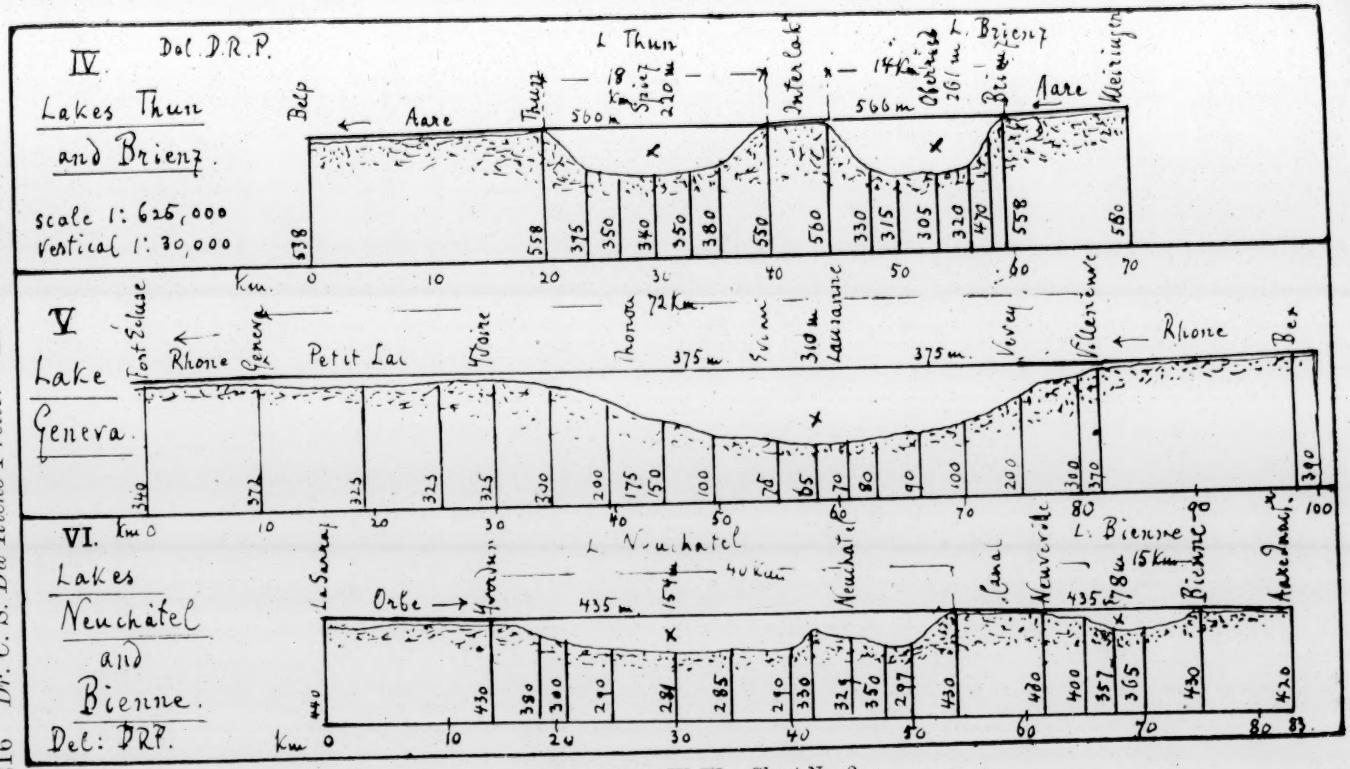
V.—The Zonal Lake Basins of sub-Alpine Switzerland.

By C. S. Du Riche Preller, M.A., Ph.D., M.I.E.E., F.G.S., F.R.S.E.

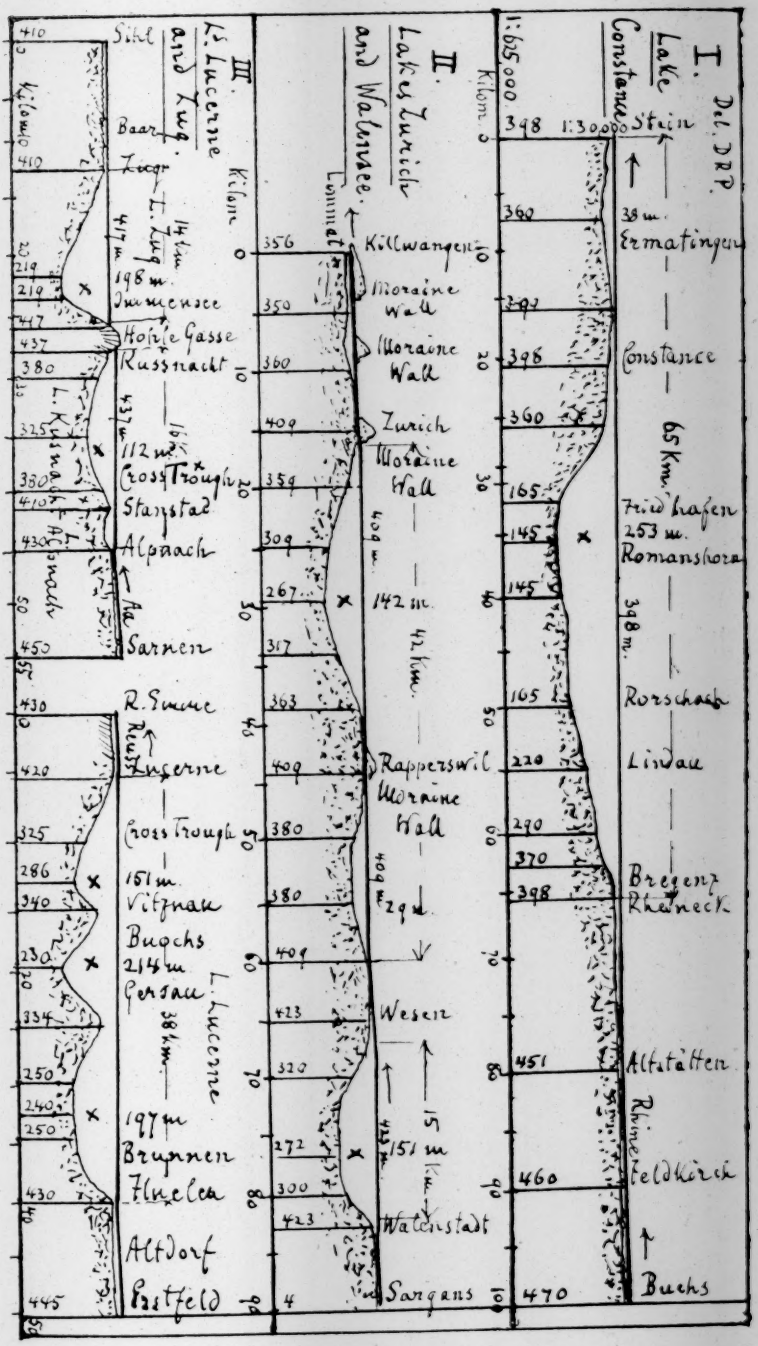
IN two papers read before the Geological Society in 1904[2] I showed that the five principal lake basins of sub-Alpine Switzerland lie in a zone which is parallel to the Alps, and that this zone lies almost

[1] Cf. G. H. Parker, "The Locomotion of Actinians": Science, March 26, 1915, p. 471.

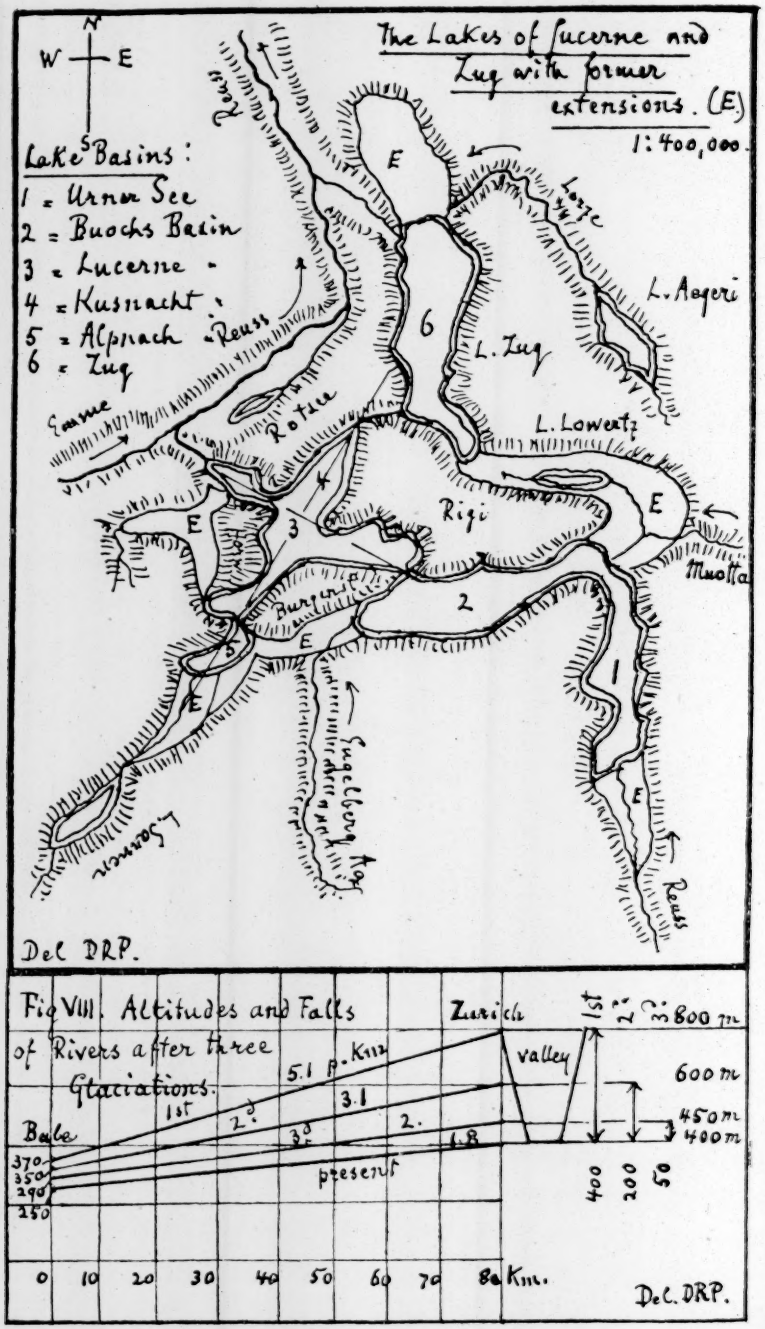
[2] Q.J.G.S., vol. lx, pp. 65, 316, 1904.



Sections. Figs. IV–VI. Sheet No. 2.



Longitudinal sections. Figs. I–III. Sheet No. 1.



Figs. VII, VIII. Sheet No. 3.

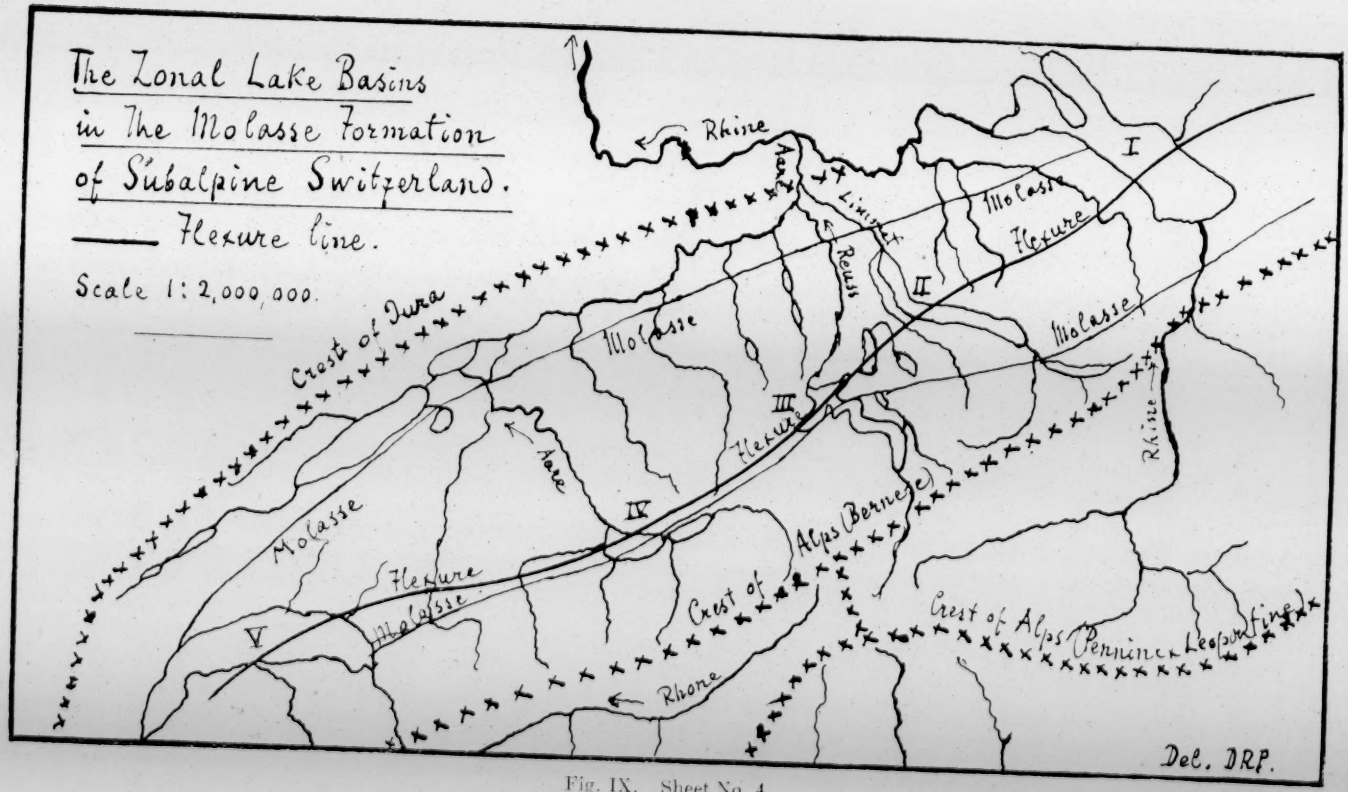


Fig. IX. Sheet No. 4.

entirely in the Molasse formation. The conclusions which I drew from these facts as to the age and origin of these basins having, since then, been confirmed by further evidence, it will not be without interest to return to the subject.

I. The Lake Basins.

The following table and the accompanying longitudinal sections, pp. 216–17, Sheets 1 and 2 (Figs. I–V), outline the salient features of the five zonal basins, to which are added (Fig. VI) those of the lakes of Neuchatel and Bienne because, although not zonal in respect of the other lakes, they present certain features common to all of them. All the dimensions are given in metric measure so as to correspond to the Swiss contour map from which the sections are plotted.

Lakes.	Former Length.	Present				
		Length.	Greatest Width.	Area.	Altitude.	Greatest Depth.
	km.	km.	km.	sq. km.	m.	m.
I. Constance .	100	65	12	539	398	252
II. Zurich . .	65	40	4	88	409	143
Walensee .	25	15	2	23	423	151
III. Lucerne .	50	38	3	94	437	214
Kusnacht .	22	16	2	20	437	112
Zug . .	19	14	4	38	417	198
IV. Thun . .	38	18	3	48	560	217
Brienz . .	24	14	2	29	566	261
V. Geneva .	110	72	10	582	375	334
VI. Neuchatel and Bienne	83	55	10	280	432	154

From the table and the sections it will be seen that all the lakes have lost at least one-third of their former length. At the upper ends the shrinkage is due to filling up by post-Glacial fluviatile alluvia, viz. mud, sand, and gravel; in the Rhone and Rhine valleys to some extent also by superficial deposits of loess borne by the Fœhn, while at the lower ends it is largely the effect of banking by the post-Glacial deposits of rivers which discharge into the lake valleys more or less at right angles immediately below or above the present outflow of the lakes. The only exception is the Lake of Constance, which at its lower end lies entirely in a moraine basin, the shrinkage being due to moraine material retransported by the Rhine.[1]

A peculiar and very complex case is that of the Lake of Lucerne, *ante*, p. 218, which, as shown in Fig. VII, is composed of five, and,

[1] In the other lakes the fluviatile bars were formed by the following rivers: in the Lake of Zurich, by the Sihl; in the Walensee (an old branch of the Rhine), by the Linth; in the Lake of Lucerne, by the Emme, which, however, only deflected the Reuss instead of barring the lake; in the Lake of Thun, by the Kander; in that of Brienz, by the Lutschinen delta of Interlaken; in the Lake of Geneva, by the Arve; and in the Lakes of Neuchatel and Bienne, by the Aare.

including the Lake of Zug as a former integral part, of six distinct basins. Of these, three are longitudinal, and the other three transversal basins, the whole forming an irregular cross whose point of intersection marks the point of greatest depth. The original course of the Reuss was through the Schwyz valley along the northern base of Rigi and through the Lake of Zug, which course, in the lapse of time, it left to follow the southern base of Rigi and erode the defile immediately below Lucerne. Here it struck, and was deflected at right angles by, the River Emme, of whose junction with the Reuss, much larger and at a higher level than at present, the small Rothsee is a remnant. The effect of the Reuss changing its course was the lowering of the level of the Lake of Zug and the severing of its connexion with the Lake of Kusnacht. The plan shows the former extent of the intercommunicating basins in the trough between Rigi and Pilatus, in which the Burgenstock and Horw ridges appeared as islands. The shrinkage of the lakes amounts to more than one-half of their former aggregate length.

But the shrinkage of the lakes is not confined to their upper and lower ends, for, as shown in the sections, the lakes are gradually being filled up within their present areas, not only by the material transported and deposited in them by the main rivers, but largely by the delta deposits of the direct affluents of the lakes,[1] and in addition, by the lake deposits *per se*, the lake chalk or 'alluvion impalpable', which covers the lake floors in some cases to an unknown depth.

From these considerations it follows: (1) That, under the climatic conditions of the present time, the lakes are in course of being gradually filled up, and that this process would be much more rapid were it not for the great depth of their central portions and for their artificial preservation by canalization of the inflow and outflow. (2) That any lakes existing before the last glaciation were probably filled up and reduced to river valleys much more rapidly and completely than the present ones,[2] *à fortiori* because they were probably large, shallow, and often intercommunicating expanses of water rather than circumscribed lakes, in which the Alpine rivers, in their then erratic courses and subdivided channels, deposited material much more copiously than the rivers of the present time.

II. Lakes and Glaciations.

It has been affirmed by no mean authority[3] that the glaciers passed over, and deposited their moraines at the lower ends of the lakes and thus preserved them [*sic*]. Even if the present lakes had existed before, and had placidly endured throughout the Ice Age, the proposition of their being bridged by the glaciers, as it were, in

[1] The most formidable of these deltas is probably that of the Drance at Thonon (Savoy), which projects already 2 kilometres into the Lake of Geneva.

[2] Of this, striking evidence is afforded by the interglacial gravel beds near Zurich, the material of which, being strictly fluviatile, can only have been transported across the filled-up lake by a river.

[3] Heim, *Gletscherkunde*, 1885, p. 542; also Favre, *Récherches Géol.*, 1867, p. 210.

a single span, appears physically and mechanically impossible, the more so when the sequence of phenomena of a general glaciation is borne in mind. This sequence may be briefly stated as follows:—

Upon a general advance of the glaciers, the rivers gradually decrease in volume, velocity, and erosive energy, and the level of the lakes drops proportionately. When the glaciers reach the heads of the lakes, the latter, if they have not already been filled up by fluviatile deposition, gradually empty themselves through the natural outlets, and the supply from their drainage areas gradually failing, become reduced to meandering river channels and pools which, taking the temperature of the ice, freeze as the glaciers advance.[1] When these, after traversing the filled-up lake basins, become stationary, they deposit moraine walls round their terminal lobes, and in front of these walls flat glacis-cones of fluvio-glacial material are formed by the deposits of glacier streams flowing round and under those walls. When, lastly, the glaciers begin to melt and retreat, lakes form behind the moraine walls and gradually increase in length and size in the wake of the receding glaciers. At their lower ends the lakes at the same time find an outlet by a stream overflowing the moraine bar at its lowest point, generally at the margin and not in the middle of the bar, and thus the work of erosion begins both in the bar and in the glacis-cone, though the main stream often, as it were by caprice, erodes its bed round the edge, instead of through the cone. As the glaciers recede beyond the lake basins, the affluents of the latter, too, become active again, and thus new lakes are formed, probably different in size, depth, and altitude from their predecessors, only, in their turn, to be filled up again.

The diagram (Fig. VIII), p. 218, shows the average fall of the principal sub-Alpine rivers after the three glaciations, as evidenced by the river deposits—indicating the valley floors—of each period. It will be seen that the average fall, and therefore the erosive energy and carrying capacity, decreased with each glaciation and is lowest in the post-Glacial rivers of the present time.[2] It will further be seen that the rivers must have been flowing at much higher altitudes than at present, and that the same altitudes apply *ipso facto* to the lakes, the valley floor and lake level, e.g. at Zurich, having been 400, 200, and 50 metres higher than at present, and the altitudes in respect of the Lake of Geneva and the Rhone at Lausanne and Geneva being about the same. Thus each glaciation must have been followed by a very long period of erosion, the longest being that between the first and the maximum glaciation, during which the valleys were approximately eroded to their present depth, while after the maximum and the third glaciations the rivers had only to remove the products of

[1] For instance, a glacier, to traverse a filled-up lake basin 40 kilometres in length, like that of Zurich, at the rate of 0·3 m. = 1 foot per day, would require over 300 years, and in the case of the Lakes of Constance and Geneva double that time.

[2] The diagram refers to the area of the junctions of the sub-Alpine rivers between Zurich and Bale. In the Alpine valleys the former higher level of 400 metres would place the then valley floor, e.g. in the Linth Valley, on a level with the present Klöntal Lake, a hanging valley 400 metres above Glarus.

these two glaciations, which filled the valleys to the altitudes given above.[1]

It follows then (1) that the present lakes were formed during, and primarily in consequence of the last general retreat of the glaciers, in other terms towards the end of the Glacial Period; (2) that the lakes, like the main rivers which traverse them, were, at the time of their formation, at levels about 150 feet higher than at present, and that they gradually dropped to their present levels as the rivers eroded their beds more deeply in the Alpine valleys above and in the sub-Alpine valleys below them; (3) that the present lakes afford no criterion as to the extent or depth of previous—Interglacial or pre-Glacial—lakes which in any case must have been formed at much higher altitudes.

III. The Lakes and the Molasse Flexure.

The lakes having been primarily formed as shown in the preceding paragraph, it remains to explain the great depth of their central portions. In this connexion the theory of glacial erosion must be discarded, for a glacier, though it can scour, abrade, level, and polish, cannot perform the mechanical work of excavation. It has volume, but no effective velocity, and even its volume, not moving as a rigid mass, is rendered ineffective by its constant state of internal friction and deformation.[2] The depth of the lakes could be more easily explained by so many rifts at right angles to the trend of the Alps, were it not that the disruptive agency as the primary cause is wanting.

The only possible and logical explanation of the phenomenon must, therefore, be sought in a slow, simultaneous subsidence of the lake floors by a zonal bending of the Molasse formation in which the lake basins lie. A line drawn through the deepest points of the five lakes will be found to run parallel to the crest, and along the edge of the Alps, within but close to the western limit of the Molasse formation. This cannot be an accidental phenomenon; it constitutes, in fact, the syncline of the main flexure of the Molasse as shown in the plan (Fig. IX), p. 219.

Of this flexure the Molasse strata themselves afford conclusive evidence at various points. Renevier recognized its anticline as running from Savoy across the Lake of Geneva and thence north-east as far as the Canton of Appenzell (Lake of Constance), and deduced from it, though without reference to the lakes, "l'affaissement sur la lisière des Alpes," which corresponds to Heim's 'Einsenkung' or

[1] Some Swiss lowland Deckenschotter deposits at a somewhat lower level than the typical high-level ones led Mühlberg, Penck, and Brückner to assume a fourth glaciation (in the Tyrol even five), intermediate between the first and maximum glaciations; but those lower deposits may be, like that of Teufelskeller, near Baden, west of Zurich, due to local subsidence.

[2] On the other hand, a big glacier is indirectly a potent factor in valley-making and valley-shaping by the disintegrating action of frost and of the great differences between extreme temperatures on the mountain-sides as well as by its great lateral and vertical pressure. In this action lies obviously the *via media* between the extreme views *pro* and *contra* glacial erosion.

lowering along the base of the Alps as the latest effect of the raising of that chain in Tertiary times.[1]

The gradual lowering of the lake floors must have begun after the maximum glaciation, for in the Zurich Valley the older moraine was lowered with it, being now buried deeply below the present valley floor and overlain by the younger Interglacial and post-Glacial gravel beds. Thus the flexure must have continued throughout the last glaciation and reached its maximum of syncline at the time of the retreat of the glaciers, that is, towards the end of the Ice Age.[2]

As regards direct evidence of the Molasse flexure, my own investigations of the subsidence of the whole area between the Lakes of Zurich and Zuy have been described in previous papers, as have also the phenomena along the northern slopes of the Lake of Geneva.[3] These investigations fully confirmed Renevier's conclusions as to the flexure, which is indeed patent to anyone familiar with the general reverse dip of the Molasse banks, cliffs, terraces, and knolls, often conformably overlain by moraine and stratified gravel, between Lausanne, Vevey, and Clarens.[4] In the basins of Thun and Lucerne the conditions of the Glacial and Interglacial deposits are, owing to their closer proximity to the Alps, less clearly defined and somewhat more complicated than in the other basins. But here, too, there is abundant evidence of the bending process, and the more the subject is studied the more will it be realized that it is to the zonal Molasse flexure with its syncline in the deepest and central portions of the five lake basins that the lakes themselves chiefly owe their existence and their preservation.

VI.—The Genesis of Chiastolite; and its suspected Occurrence in Association with a Basic Intrusive.[5]

By Alfred Brammall, B.Sc. (Lond.), F.G.S.

(PLATE VIII.)

Introduction.—The following account of the alteration produced in shale by the sill-like intrusion at Marston Jabet, near Nuneaton, supplements the more general paper dealing with the intrusion as a whole. (See Geol. Mag., April, 1915, pp. 152–8, Plate VI.)

[1] Renevier, *L'Axe Anticlinal de la Molasse*, 1902; Heim, *Beiträge*, xxv, p. 475, 1891.

[2] The retreat of the glaciers must have been of very long duration, for in the Zurich sub-Alpine valley alone there are no less than four successive moraine bars across it, each of which is evidence of a long stage in the recession.

[3] A similar instance of zonal subsidence appears to be that of the Cleveland (Yorks) and the Black Combe (South-West Cumberland) "ancient glacier lake" districts, both of which, according to P. F. Kendall and B. Smith, were in pre-Glacial times at higher levels than at present (Q.J.G.S., vol. lviii, p. 471, 1902; vol. lxviii, p. 402, 1912).

[4] In 1906 an instructive section was exposed at Clarens at a junction of roads about 60 metres above the lake, showing about 20 metres of moraine with overlying stratified gravel dipping reversely like the rock strata in the immediate vicinity.

[5] A supplement to the author's paper on "The Intrusive Rock of Marston Jabet, Nuneaton, Warwickshire", which appeared in the April Number, pp. 152–8, Plate VI, 1915.

Normal Alteration Effects.—Though the alteration produced in the shales by the intrusive sheets is of the low grade and small extent usual for such intrusions, the effects include features hitherto recorded as occurring only within the contact zone around acid intrusives.

Shale taken from an horizon about 5 feet above the upper limit of the higher sheet shows no certain evidence of thermometamorphism beyond induration. Within the alteration zone proper (varying from 3 inches to 2 feet in vertical depth) the progressive alteration is as follows:—

1. Normal black shale, without pyrites.
2. Harder, fissile 'card' or 'biscuit' shale, with pyrites, developed mainly along the planes of separation.
3. A lighter-coloured, more compact rock: the shale has been partly bleached by the dissipation of the carbon content; the fissile character is less pronounced, the traces of the separation planes being pencilled out by pyrites.
4. A greyish, compact, sub-porcellanous rock, having the appearance of adinole.

The microscopic appearance of the two end terms of this series is described in the Appendix.

A suspected occurrence of Embryonic Chiastolite.—Of exceptional interest, however, are features observable in the shales which have suffered alteration either (1) as xenolithic slabs enclosed in the thicker sheets of igneous rock or (2) as the platform forming the floor of a sheet. Thin sections from the non-porcellanous zone of card-shale have the following features:—

1. The base is a pronounced reddish-yellow.
2. Granular pyrites is extremely abundant, as spheroidal aggregates with radial structure disposed mainly along the bedding planes.
3. Opaque (? carbonaceous) matter is present in considerable quantity.
4. The base has suffered a partial recrystallization, of an unexpected character. It is largely made up of a mineral giving rhombic, square, and polygonal sections, the boundaries of which are neatly pencilled out with dark opaque matter—possibly the excretive effect of crystallization, for the outer zone of each section is comparatively free from included opaque matter which, however, is frequently massed at the centre and less frequently at the corners or disposed along diagonals. These sections give aggregate polarization (1st order greys and yellows); hence, neither refractive index nor interference figure nor sign of birefringence is determinable for the original mineral, which has obviously paramorphed or been pseudomorphed.

No indication whatever of the crystal content of these altered shales is visible in the hand-specimen; yet it is difficult to avoid the conclusion that the crystal sections in question represent embryonic imperfectly individualized chiastolite, which by increment of alkali or possibly lime has been pseudomorphed to a schimmer aggregate.

Discussion of the Genesis of Chiastolite.—If this conclusion be correct, the occurrence of chiastolite is less restricted than is at present supposed.

Chiastolite is usually described (somewhat loosely) as a *variety* of andalusite; but though the two have the same empirical formula (Al_2O_3 . SiO_2), the same crystal form, and the same (negative) sign of birefringence, the specific gravity of andalusite is constantly, and the degree of hardness usually, somewhat higher than for chiastolite—differences which might conceivably be an effect of higher pressure exerted on the parent rock at the time of its metamorphosis. But the inclusions of carbonaceous matter characterizing chiastolite are significant; such inclusions are essentially absent from andalusite, which, moreover, frequently occurs in gneissose and acid igneous rocks in such a manner as to leave no doubt as to its pyrogenic origin (whether from the fusion of aluminous xenoliths, or as a normal product of crystallization from a highly alumino-silicic magma, or otherwise, is immaterial to the present discussion). The assertion that chiastolite is merely a variety of andalusite may be true in this sense:—

(1) That the temperature range within which the orthorhombic silicate of alumina of empirical formula Al_2O_3 . SiO_2 can be produced is very wide; and

(2) That if the silicate is initiated at a temperature nearer the lower than the upper limit—a temperature too low to dissipate (by oxidation) the entangled carbonaceous matter—the latter is constrained by crystallization to take up the diagonal orientation characteristic of chiastolite; and

(3) That if the silicate is produced at a temperature sufficiently high to dissipate the carbon and under pressure, the product is andalusite.

But if the upper limit of the 'chiastolite-andalusite' temperature range be passed at ordinary pressure by heating andalusite to 1320° C. this mineral paramorphs to sillimanite[1] (also orthorhombic but more acicular in habit and of positive birefringence); thus 1320° is the 'transition point' (at ordinary pressure) from andalusite to sillimanite, which may therefore be regarded as distinct 'phases', i.e. definite mineral species; and by analogy a temperature (much below 1320° C.) at which carbonaceous inclusions in chiastolite can be dissipated may be regarded as the 'transition point' from chiastolite to andalusite; and the question arises as to whether chiastolite *is* merely a variety of andalusite any more than andalusite is a variety of sillimanite.

Again, chiastolite is clearly a 'low temperature' product; and it is highly probable that the temperature range for its production is consistent with the presence of water, as such, at the time of, and possibly as essential to, the nativity of the mineral. Assuming only the mere *presence* of water, however, the production of the mineral in rocks of appropriate composition

(1) Depends upon the maintaining of a comparatively low temperature—within a restricted range; and

(2) Is effected in the presence of water (meteoric or juvenile) which may be essential either (*a*) as the sole mineralizer or (*b*) as the carrier of mineralizers more potent than itself—emanations or leachings from igneous magmas.

[1] W. Vernadsky, Bull. Soc. Min., vol. xiii, p. 256, 1890; Compt. Rend., vol. cx, p. 1377, 1890.

A. Brammall, Photo. Bale, Sons and Danielsson, Ltd.

Sections of altered Shale, showing embryonic crystals of Chiastolite.
Marston Jabet, near Nuneaton.

By virtue of (1) above, whatever be the chemical composition (acid or basic) of the igneous intrusion effecting metamorphosis, the temperature gradient, from the focus to the periphery of the aureole, should traverse a zone within which the temperature appropriate to the production of chiastolite is maintained for a shorter or longer time; hence, if heat alone (dry or moist) conditions the production of chiastolite in argillaceous rocks, the assertion (met with in most text books) that the occurrence of chiastolite is *restricted* to such rocks around *acid* intrusives is without obvious explanation.

If, however, the production of chiastolite is conditioned by heat and mineralizers carried by water, this restriction receives explanation at once, since the volatile content of acid magmas is notably higher than for basic magmas. The latter (a pneumatolytic) hypothesis, however probable, yet lacks definite experimental support, while on the other hand there is little to urge against the reasonableness of seeking chiastolite where its presence has not hitherto been recorded, that is, in argillaceous rocks altered by contact with basic intrusives, and if a search should prove occasionally fruitful such inconspicuous occurrences of chiastolite might even be regarded as special cases supporting the pneumatolytic hypothesis, in this sense: that as the volatile content of basic magmas is lower than that for acid magmas the purely pneumatolytic effect of the former will be less than for the latter, the 'chiastolite zone' will be narrower and less distinctive, and the mineral itself less perfectly developed—even only embryonic; and the occurrence described in this paper is urged as a special instance of the latter character.

Conclusion.—Similar occurrences elsewhere may have escaped detection for the following reasons:—

(1) The chiastolite is embryonic—too imperfectly developed to be conspicuous in hand-specimens of the parent shale; and may not have been sought for because its presence was not suspected.

(2) The zone of production either does not extend to the surface of the ground or is limited in width to a few inches; and even at greater depths the zone may still be very narrow and the mineral embryonic.

Appendix: Microscopic Features of Shales in Thin Section.

Shale No. 1.—An umber-coloured almost opaque base of finely divided matter, crystalline in part (since there is polarization, in low order greys and yellows) but of indeterminate nature; carbonaceous matter abundant; specks of sulphidic ore occasional.

Shale No. 4.—A light almost wholly transparent base, containing but little opaque (? carbonaceous) matter; pyrites conspicuous, as aggregates with radiate structure. Mainly composed of minute irregularly bounded grains of a crystalline substance showing fairly good relief and polarizing in 1st order greys and yellows. Irregularly distributed in the base are patches and strings of minute raggy flakes closely resembling sericite or paragonite.

EXPLANATION OF PLATE VIII.

Figs. 1, 2.—Photomicrographs of thin sections of altered shale parallel to bedding planes taken in ordinary transmitted light. Rhombic, square, and polygonal crystal sections can be made out in each of these figures, and the specific features of chiastolite are also distinctly discernible.

Note.—The possibility that these embryonic crystals (Figs. 1 and 2) may be *scapolitic* is not overlooked. Scapolite is occasionally developed as a contact mineral in argillites around basic intrusives, being restricted to a narrow zone at the contact. The optical features of such scapolite are often obscured by carbonaceous matter present as inclusions, while the mineral itself is often decomposed to a matted aggregate of mica-like flakes (colourless chlorite—'leuchtenbergite'). So far, therefore, the parallel between such occurrences of scapolite and the mineral now in question is complete; but the shape of the sections and the distribution of the carbonaceous matter give the latter a strikingly chiastolitic appearance, while the content of lime and alkali in the shales is much too low to favour the development of scapolite.

VII.—A Contribution to the Petrology of North-Western Angola.

By Arthur Holmes, B.Sc., A.R.C.S., F.G.S., F.R.G.S.

(WITH A MAP, PLATE IX.)

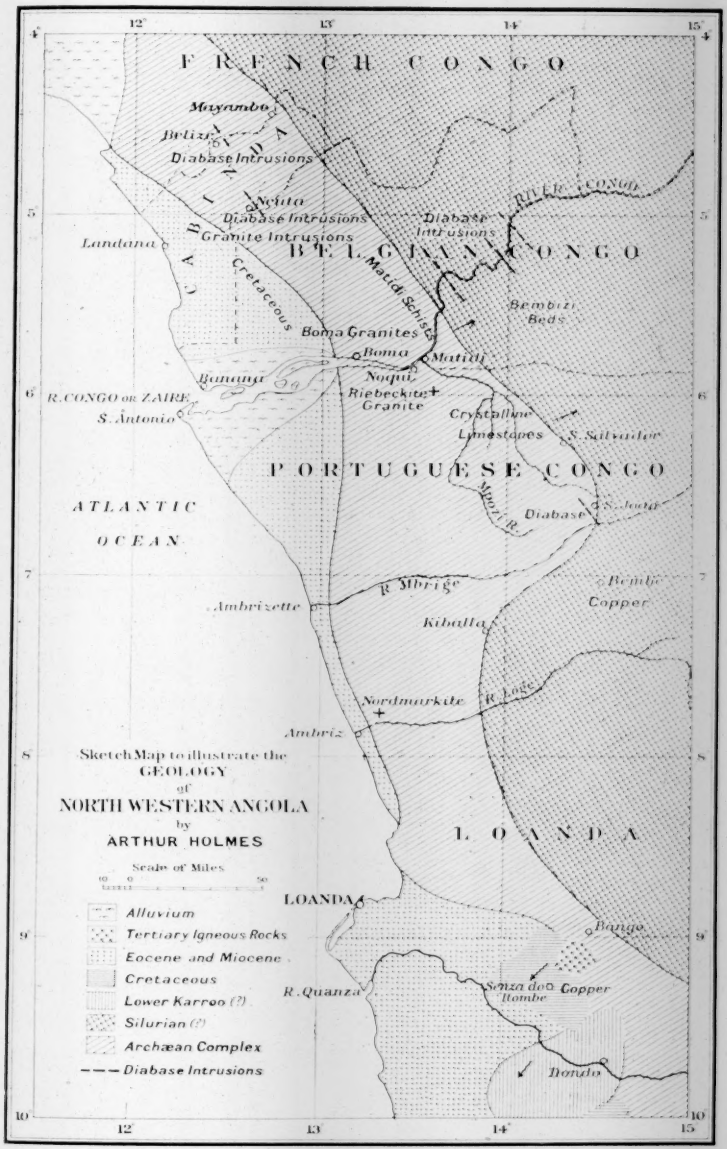
1. Introduction.
2. Bibliography.
3. Notes on the Geology of North-Western Angola.
4. Ægirine-Riebeckite Granite from the Lower Congo.
5. Alkaline Igneous Rocks between Senza do Itombe and Bango (Loanda).

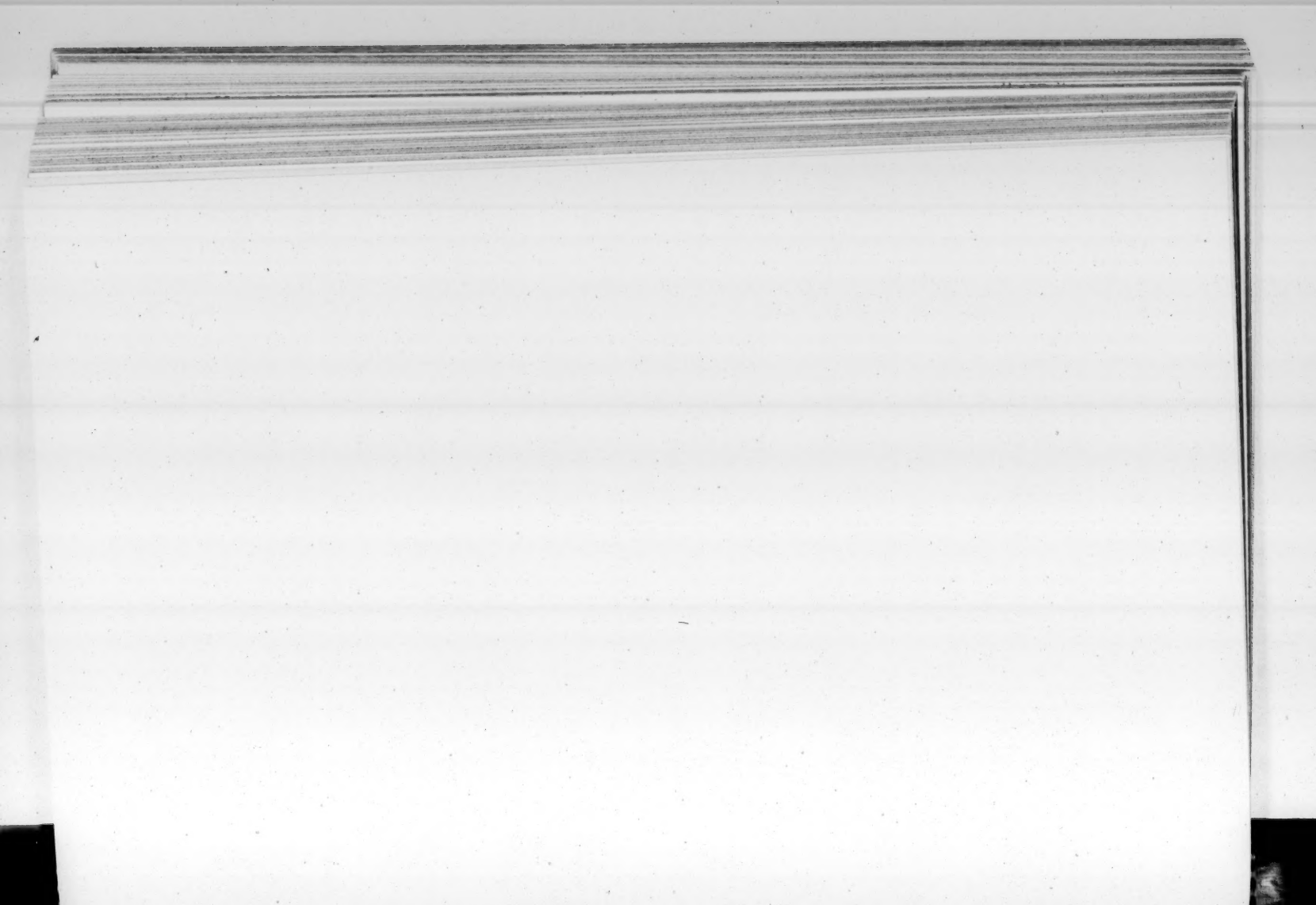
1. Introduction.

LAST year I received from Colonel Freire d'Andrade a number of interesting alkaline igneous rocks, from a valuable collection made by him during an extensive exploration in North-Western Angola undertaken some years ago. Until recently our knowledge of the geology of that part of Africa was very scanty. Already in 1897 Cornet had described the western tongue of the Belgian Congo which separates the Portuguese provinces of Cabinda and Congo. Moreover, the occurrence of copper ores at Bembe and Senza do Itombe had attracted some geological attention, but it was not until Colonel Andrade's journey that any systematic geological observations were made over a large area of the territory. Since then a number of prospecting expeditions have been conducted by J. J. MacHugh, the results of which serve to extend our knowledge to the south of the area described by Colonel Andrade. In view of the inaccessibility of much of the literature dealing with Angola, it may be interesting, before giving petrological details of some of the rocks, to present in English a short sketch of the geology of part of Portuguese Congo and Loanda, embodying the observations made by Andrade and MacHugh.

2. Bibliography.

1. Andrade, Freire d'. "As minas de cobre da provincia d'Angola": Revista de Obras publicas e minas, vol. xxxvii, No. 436, pp. 275–315, 1906.
2. Barradas, J. F. "Diario relatorio sobre a formação geologica encontrada durante a recente expedição através da Quissama e parte da região do Amboim e Libolo por J. J. MacHugh, 1909": Revista portuguesa colonial e maratima, No. 149, pp. 219–26, 1910.


FRENCH CONGO
Mayumba
Belize
Diabase Intrusions
Ngula
Diabase Intrusions
Granite Intrusions
Diabase Intrusions
RIVER CONGO
Landana
BELGIAN CONGO
Cretaceous
Matidi Schists
Bembizi Beds
Boma Granites
Boma
Matidi
Banana
Noqui
Riebeckite Granite
R. CONGO or ZAIRE
S. Antonio
Crystalline Limestones
S. Salvador
PORTUGUESE CONGO
ATLANTIC OCEAN
Mpozi R.
Diabase
S. Jose
R. Mbridge
Bembe Copper
Ambrizette
Kibalia
Nordmarkite
R. Loge
Ambriz
Sketch Map to illustrate the GEOLOGY of NORTH WESTERN ANGOLA by ARTHUR HOLMES
Scale of Miles
Alluvium
Tertiary Igneous Rocks
Eocene and Miocene
Cretaceous
Lower Karroo (?)
Silurian (?)
Archæan Complex
Diabase Intrusions
LOANDA
LOANDA
Bango
R. Quanza
Senza do Bombe Copper
Bondo



3. BARRAT, M. "Sur la géologie du Congo français": C.R., Oct. 1884; Ann. des Mines, p. 379 (map), 1895.
4. CHOFFAT, P. "Coup d'œil sur la géologie de la province d'Angola": Comm. da Dir. dos Trab. geol. Portugal, vol. iii, p. 84, 1895.
—— "Matériaux pour l'étude stratigraphique et paléontologique de la province d'Angola": Mém. Soc. Phys. Hist. Nat. Genève, vol. xxx, No. 2, 1888.
—— *Bibliographie géologique du Portugal et de ses colonies*, sér. VIII (1906–7); "Communiçoes" du Service géologique du Portugal, vol. vii, 1909; Sér. IX (1908–9), vol. viii, 1911; Sér. X (1910–12), vol. ix, 1913; Sér. XI (1913), vol. x, 1914, esp. p. 17, No. 44.
5. CORNET, J. "Géologie du Congo occidentale": Bull. Soc. Belge Géol., vol. xi, 1897.
6. MACHUGH, J. J. "Reconhecimento ás minas de cobre do Zenza e do Bembe": Boletim de Agricultera—Governo geral da provincia de Angola, No. 6, pp. 265–9, 1909. See also J. F. Barradas.
7. SOUSA, Pereira de. "Contribution à l'étude petrographique du nord d'Angola": C.R., vol. clvii, p. 1450, 1913.
8. STUDT, F. E. "An Outline of the Geology of South Central Africa": Trans. Geol. Soc. S. Africa, vol. xvi, pp. 85–7, 1913.
9. VOIT, F. W. "The Copper Deposits of Senzo do Itombe": Zeit. Prakt. Geol., p. 86, 1899; p. 353, 1902.

3. NOTES ON THE GEOLOGY OF NORTH-WESTERN ANGOLA.

As indicated in the adjoining sketch-map, this part of Africa is characterized by three well-marked belts. The middle belt consists of a complex of gneisses and schists through which later intrusions, chiefly of granulitic granite with their attendant pegmatites, and of diabase, have penetrated. On this typical Archæan basement lie the Cretaceous and Tertiary beds of the coastal plain, and the old sedimentary formations which form the plateau of the interior.

Archæan Complex.—The oldest rocks of the territory, as elsewhere in the equatorial coast lands of Africa, are represented by schists, crystalline limestones, and sediment gneisses. Between the Tertiary beds of Landana and the French frontier at Mayambe, mica-schists, quartzites, quartz-epidote and epidote schists, and felspathic sediment (arkose) gneisses occur, with local bands of chlorite, hornblende, and hæmatite schists. Generally underlying the schistose rocks, but showing intrusive contacts in places, is a vast foundation of gneissose granites (primary granite gneisses of some authors) with interfoliated hornblende gneisses and amphibolites. The gneissose granites contain albite, oligoclase, and microcline, an association of felspars which is highly characteristic of the oldest granites throughout Africa. The lithological features of these gneissose and schistose rocks justify one in assigning them to the Archæan. Intrusive into the fundamental complex is a series of granulitic granites which are well exposed near Ncuta. Diabase dykes and sills which have suffered uralitization are found near Ncuta and Belize. They appear to be younger than the Palæozoic sedimentary rocks which appear near the French frontier, for similar diabase intrusions penetrate the old sedimentaries where they cross the Congo to the south-east. In this district, the Belgian sphere of the lower Congo, Cornet has recognized a similar succession. The Matadi schists are intimately associated with gneisses and amphibolites, and the whole complex is intruded upon by the Boma granites.

To the south of the Congo, again in Portuguese territory, mica-schists and quartzites occur along the road from Noqui to San Salvador. The schist series differs in this locality from its northern continuation in the comparative rarity of epidote-bearing rocks, and by the appearance of numerous bands of crystalline limestone. Near the River Mavumi gneissose granites are exposed. Granulitic granites are found just south of the Congo, similar in structure to the Boma granites, and remarkable for their high content of albite. In many places they are injected in sheets between crystalline limestones and other members of the schist series, and in the former, interesting contact minerals, such as chondrodite and diopside, have been developed. Syenites occur between Tombo and the River Lalu. At kilometre 16 on the Noqui – San Salvador road the limit of the albite granites is reached, and at this point Colonel Andrade found a variety containing a relatively high percentage of riebeckite, accompanied by ægirine. This rock, a splendid example of an interesting type of which very few occurrences are known, is described in detail below. It illustrates Harker's view[1] that alkaline rocks, and especially unusual types, tend to occur on the margins of igneous provinces.

Between Bembe and the coast at Ambriz, the schists and gneisses are not seen until Kiballa is passed, after which they continue to the coastal belt, where they disappear under a thin narrow band of Tertiary formations. Near the mission station of San João intrusions of diabase are found, the only examples of this rock met with in Portuguese territory south of the Congo. At kilometre 19 between the coast and Bembe the western peripheral phase of the granulitic granites is represented by a fine-grained reddish rock which is described by M. de Sousa as a *nordmarkite*.[2] It therefore seems to differ from the ægirine-riebeckite granite already mentioned only in the possession of arfvedsonite in place of riebeckite.

Palæozoic Rocks.—Lying unconformably on the basal complex is a system of old sedimentary rocks which includes two distinct series of formations. In the enclave of the Belgian Congo Cornet has described a lower series which he calls the Bembizi Beds, including conglomerates, calcareous sandstones, shales, and slates, and an upper series, the 'schisto-calcareous' beds, made up of dolomites with chert bands. Their prevailing dip is away from the coast towards the central part of the Congo Basin. Passing inland, the lower beds, which are exposed in narrow strips around the schist boundaries, are everywhere followed by the overlying dolomite series.

Around Mayembe the two series are represented by calcareous sandstones and cherty limestones respectively. Further south, between San Salvador and Bembe and from there to Kiballa, thick beds of arkose, quartzite, and calcareous sandstones are surmounted by dolomites and limestones.

The age of this system is doubtful. Micro-organisms have been found in the limestone of Mayembe, but they are so ill-preserved as to be indeterminable in sufficient detail to serve as an index of age. Further south, however, the system continues through Benguela and

[1] Pres. Ad. Brit. Assoc. Rep. for 1911, p. 370.
[2] Brogger, *Zeit. Kryst.*, xvi, p. 55, 1890.

Mossamedes to Damaraland, where a thin series of conglomerates and arkose beds is followed by the famous Otavi dolomites. *Orthoceras* has recently been found in the latter formation, and it is therefore certain that the dolomites are not older than the Silurian.[1] Barrat considered the Angola and French Congo equivalents to be of Devonian age, but the basis of his correlation is of doubtful value as it depends only on lithological comparison with the rocks of far distant areas. Subject to the same criticism is Studt's correlation of the Otavi dolomites with the Dolomite series of the Transvaal system and the dolomitic beds of the Cango Series.

Important copper deposits are found in the Bembi dolomites and limestones, occurring in the same way as those of the Otavi dolomites, and of the still more valuable Katanga (Kambove) dolomites. All these dolomites are probably of Silurian age, but the copper ores are not altogether confined to this horizon, as they occur also in the schists of Angola and in the Cenomanian calcareous grits and conglomerates of Senza do Itombe.

Karroo (?) *Formation.*—In the basin of the Quanza River, around Dondo, a coal-bearing formation has been known for many years. It rests unconformably on the Palæozoic limestone and on the Archæan complex, and dips gently towards the south-west. The lower beds contain oil-shales and a thick seam of coal, and are followed by grey grits and conglomerates, above which lies a much coarser conglomerate which is characterized by a chocolate or reddish tint. Similar grey and red grits, but without the coal-bearing formation, are found on the Palæozoic rocks of the French Congo. It seems probable, from their lithological characters and position in the sequence, that the carbonaceous rocks of Angola are of Lower Karroo age. They are certainly post-Silurian and pre-Cretaceous.

Cretaceous and Tertiary.—The Cretaceous beds of Senza do Itombo lie unconformably on the Karroo and the Archæan, and dip to the south-west. Elsewhere Cretaceous rocks unconformably underlie the Tertiary deposits of the coastal belt, but they are recorded only in vague terms, and their distribution cannot yet be laid down on a map. The Tertiary limestones and sandstones extend along the coastal belt uninterruptedly, except for a doubtful break south of Ambriz, where their outcrop narrows down to a mile or two. Both Eocene and Miocene fossils have been collected, but the distribution of the two types, and the possibility of an unconformity between them remain to be worked out. Alluvial deposits and lateritic sands and gravels form a widespread blanket along the coastal belt, adding a further obstacle to the inherent difficulty of mapping in a tropical country.

Tertiary Igneous Rocks.—Between Senza do Itombo and Bango an interesting series of alkaline igneous rocks was discovered by Colonel Andrade. They are apparently intrusive into both Karroo and Cretaceous formations, and in common with the similar igneous rocks of the Kamerun and Adamaua, they are most probably of Tertiary age. Lava-flows, associated with plutonic and minor intrusions, are all represented in this igneous suite, which includes nepheline phonolites

[1] Studt, p. 91, 1912.

and syenite, with olivine monchiquite and ulrichite containing the brown hornblende, barkevikite.

Summary.—The geological succession in North-Western Angola is as follows, rocks of doubtful position being placed on the right:—

	Recent Deposits.	
Tertiary	Miocene Eocene	Alkaline igneous rocks.
		Irruptive contact.
Cretaceous	Cenomanian.	
Karroo (?)	Red Conglomerate Grey Grits Carbonaceous Beds	Diabase Intrusions.
Palæozoic Silurian (?)	Dolomite and Limestone Series. Bembizi Beds.	
Archæan Complex	Granulitic Albite Granites.	*Irruptive contact.*
	Gneisses and Gneissose Granites.	*Irruptive contact.*
	Schists and Crystalline Limestones.	

(To be continued in the June Number.)

REVIEWS.

Memoirs of the Geological Survey of England and Wales. The Geology of the Country around Windsor and Chertsey. By Henry Dewey, F.G.S., and C. E. N. Bromehead, B.A., F.G.S. pp. i–vi, 1–123. 1915. Price 2*s.* 6*d.*

THIS memoir is an explanation of Sheet 269 of the 1 inch Geological Map. Pressure of work due to the War has, however, delayed the colour-printing of the map, and it is not yet ready for publication, but the authors give a sketch-map of the area on the scale of 4 miles to the inch. (p. 2.)

The sketch-map shows that the district is divided into three nearly equal parts: (1) mainly London Clay in the centre and west; (2) Bagshot Sand in the south; and (3) river gravels and brickearth on the north-eastern side of the area.

In the first of these parts the London Clay occupies a large tract, Windsor Park and much of Windsor Forest being upon it, and it also extends underground over almost all the rest of the district. Its thickness is about 400 feet in the east and rather less than 300 feet in the west. The Basement-bed with *Ditrupa* and shells is noted in several places and appears to be continuous. Fossils are not uncommon, and the authors give a list of considerable interest from near the top of the formation at Bracknell. There is a small exposure of Reading Beds in the north-western corner of the area, and they have been pierced in well-sections elsewhere. The thickness varies from about 100 feet in the south to 60 feet in the north. Chalk is found at the surface in the north-eastern corner of the district

and also at Windsor Castle. In the old series of Geological Survey maps the Windsor Chalk is shown as part of the main mass of Chalk of the Chiltern Hills, but, as was suggested some time ago by Mr. Whitaker, it is now proved to be a small inlier due to a post-Eocene anticline. This is explained by the authors in a most interesting horizontal section (p. 13), which shows how the Chalk of the Castle Hill projects through the Eocene formations.

The second or southern third of the district is occupied by what used to be known as the Bagshot Sands. There has been some discussion as to whether they rest, conformably or unconformably, on the London Clay, and the authors find that in part of the district the junction is conformable with passage beds, whilst in the western part there is an abrupt change of sedimentation with indications of erosion of the London Clay before the Bagshot Sands were deposited. The Bagshot Sands were divided by Prestwich in 1847 into three divisions, all of which can be more or less satisfactorily correlated with beds in the Hampshire Basin. The question thus arises whether to use the London Basin or the Hampshire Basin names, and the authors of the present work have decided to restrict the name Bagshot to the lowest of the three divisions, and to use the Hampshire names Bracklesham and Barton for the middle and upper divisions respectively. (p. 32.)

The Bagshot Beds are mainly current-bedded sands with thin layers of clay and pipe-clay and occasionally beds of pebbles. The thickness does not exceed 120 feet, and they thin to 20 feet towards the north. There are practically no fossils.

The Bracklesham Beds contain clay suitable for brick-making and beds of green sand. Fossils have been found which satisfactorily prove their Bracklesham age. The thickness is estimated at 100 feet at St. George's Hill, near Weybridge, and in the west of the district the thickness may be as much as 80 feet, but is very variable. (p. 42.) Pebble beds occur in places. Ironstone, an impure carbonate of iron, is found at the junction of the Bracklesham and Bagshot Beds, and was dug for smelting round St. George's Hill in the eighteenth and beginning of the nineteenth centuries. It is remarked that no other Tertiary iron-ore has been worked in the Thames Basin, though ore of about the same age was formerly worked at Hengistbury Head on the Hampshire coast. (p. 92.)

The Barton Beds consist of light-coloured quartzose sand with occasional beds of loam and clay and more rarely seams of pebbles. Bedding is seldom seen and current-bedding, so common in the Bagshot Beds, is exceptional in this upper series. The colour is usually yellow or buff. Very few fossils have been found in this district. This is the topmost Eocene bed in the area, and the full thickness is not preserved. The present thickness may slightly exceed 100 feet at Cæsar's Camp, Easthampstead. Greywethers or sarsen stones have been found in considerable abundance in the district, and though not seen in situ in Barton Beds, the authors think it probable that they may have been formed in them.

Much of the surface of this southern third of the district is covered by Plateau Gravel, and the authors remark that "Presuming that the

gravels are the remnants of a once-continuous sheet, they appear to have been deposited in a fan on a sloping surface which conformed in its general outline to the present configuration of the Thames valley". (p. 59). Pieces of chert probably derived from the Lower Greensand of the high ground about Hindhead are common in these gravels.

The third, eastern and north-eastern, part of the district is covered by river gravel and brickearth. It comprises the whole area north of the Thames and small tracts to the south of that river and by the River Wey. The authors separate the gravels into three terraces—the 100 feet terrace or Boyn Hill Gravels, the 50 feet terrace or Taplow Gravels, and the lower terrace or Flood-plain Gravels—and they observe that these divisions appear to correspond with the sequence of types of flint implements. Thus the Boyn Gravels are characterized by implements of Chellean and Acheulian types, while that of Le Moustier first appears in the Taplow terrace, though this contains also occasional specimens of the older forms which are probably derivative. (p. 67.)

The river gravels younger than those of the Taplow terrace are included in the Flood-plain gravels. There was a considerable area of brickearth mainly resting on gravels belonging to the Taplow terrace, but it has been largely removed for brick-making. The authors describe the Alluvium and peat, and give an interesting list of land and freshwater shells from a section near Old Windsor.

In an Appendix a considerable number of wells and borings are recorded. The Palæozoic floor has not been reached in the district, the Lower Greensand being the oldest formation touched. This is not surprising, as the base of the Gault is here at a great depth more than 1,000 feet below Ordnance datum in the tract to the south of Slough, as will be seen on reference to the maps by Dr. Strahan in his Presidential Address to the Geological Society for 1913.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

March 24, 1915.—Dr. A. Smith Woodward, F.R.S., President, in the Chair.

The President announced the Award of the Proceeds of the Daniel-Pidgeon Fund for 1915 to Mr. E. Talbot Paris, B.Sc., who proposes to continue his researches on the Lamellibranchia of the Rhætic, Lias, and Lower Oolites of England.

The following communication was read:—

"The Stratigraphy and Petrology of the Lower Eocene Deposits of the North-Eastern Part of the London Basin." By Percy George Hamnall Boswell, B.Sc., F.G.S.

The following divisions of the Lower Eocene occur in the area:—

London Clay—Basement-bed only.
The Pebble Beds and accompanying sands.
Reading Beds.
Thanet Beds.

The unconformity of the Eocene upon the Chalk is discussed, and reasons are given for regarding the layer of green-coated flints at the bottom of the Thanet Beds in the area as a true basal conglomerate. The Eocene deposits overstep the Chalk zones from the zone of *Ostrea lunata* to that of *Micraster cor-anguinum*, and also transgress the Chalk surface-contours; owing to the greater dip of the base of the Eocene, the latter also bevels off the zone in South-Eastern Suffolk.

Evidence is adduced to show that the London Clay overlaps the Lower London Tertiaries, and rests directly upon the Chalk in Norfolk. The Reading Beds also overlap the Thanet Beds in the western part of the area. A hypsometrical map of the Chalk surface in the London Basin is presented, and a minimum estimate of the unconformity, in terms of thickness of Chalk removed, is given for the northern part of the Basin.

Isopachytes for the London Clay and Lower London Tertiaries (the north-western feather-edge of each deposit being the zero isopachyte) have been plotted, and since the beds thicken on each side of a central area in South-Eastern Suffolk, where the sub-Eocene Chalk surface gradient is least, the curves are seen to be convex to a central axis. The Chalk zones, Chalk surface contours, Lower London Tertiaries, and London Clay successively change strike as they are traced north-eastwards. The instability over the axis, which may be of Charnian trend, took the form of an earth-ripple forced north-eastwards, throughout Eocene times, towards that part of East Anglia where the Palæozoic platform rises. The unconformity of the Pliocene deposits upon the Eocene and the Chalk is shown to be significant in this connexion.

Stratigraphical details of the various divisions and descriptions of new sections are given. Tables of mechanical analysis (obtained by elutriation) throw light on the conditions of disposition, and permit of the adoption of an exact terminology. The visible Thanet Beds are of two facies: (*a*) the Ipswich or Eastern type, with predominant green clays, and (*b*) the Sudbury or Western type, characterized by the prevalence of light-coloured sands.

The variations in lithology of the Reading Beds are described, and it is shown that the Pebble beds belong lithologically and petrologically to the Reading Beds, but that their scanty fauna is a London Clay one. The fauna of the London Clay is also enumerated, and the author is of the opinion that the bed was deposited under isostatic conditions accompanying a sagging on each side of the central axis mentioned above.

The distribution of the sarsens in the area is plotted out on a map, and their petrology is considered; it is concluded that, in this district, they are derived from the sands of the Reading Beds.

The mineral constitution of the various divisions of the Eocene beds is discussed in detail. The mineral assemblage is seen to conform to one type throughout (characterized by occasional small, angular, colourless garnets, also by abundant staurolite, tourmaline, and kyanite), but differences occur which allow of the beds being easily distinguished one from the other. There is remarkable constancy in mineral composition over wide areas, and in deposits lithologically

different. The mineral suite of the succeeding Pliocene beds (with abundant red garnets, andalusite, mica, and ferromagnesian minerals) is shown to be very different, and the constituents of various other East Anglian deposits are also compared.

In the Thanet Beds, ferromagnesian minerals are present and undecomposed, the micas being rare. In the shallow waters in which the Reading Beds were deposited, the biotite, hornblende, pyroxene, and epidote appear to have been largely lost, aided no doubt by current-drift along a shore. The Pebble beds show occasionally natural concentration of heavy minerals by oscillatory current-action. In the subsidence which followed when the London Clay was deposited, muscovite and biotite appeared in fair quantity, and hornblende became abundant. Such minerals as magnetite, ilmenite, rutile, zircon, glauconite, etc., are plentiful throughout.

II.—Mineralogical Society.

March 16, 1915.—Dr. A. E. H. Tutton, F.R.S., President, in the Chair.

Professor G. Cesàro: Orpiment from Balia, Asia Minor. Results of a crystallographic examination were given.—Professor G. Cesàro: Stereographic projection of a cone touching the sphere of projection along a small circle.—Dr. S. Kôzu: The dispersion of adularia from St. Gothard, felspar from Madagascar, and moonstone from Ceylon. A second communication giving the results of careful measurements. —Dr. G. T. Prior: The Meteoric Stone of Launton, Oxfordshire. The stone, which was seen to fall on February 15, 1830, was acquired by Dr. Lee and placed in his natural history collection at Hartwell House, near Aylesbury. After his death it was, through confusion with another meteorite, lost sight of until 1895, when it was found by Dr. Fletcher wrongly labelled in the Lee Collection, and was secured for the British Museum. The stone belongs to the white-veined chondrite group, and in chemical and mineral composition agrees with other members of that group.

III.—The Geological Society of Glasgow.

At a meeting of the Geological Society of Glasgow, April 8, 1915, Mr. Duncan Smith exhibited hazel-nuts and wood found in March, 1914, when preparing foundations for the restoration of Paisley Abbey. The occurrence was investigated by the Rev. C. A. Hall and Mr. Smith, who found that the nuts were in great abundance, mostly in pockets in a gravel about 11 feet from the surface. Consideration of the evidence led to the conclusion that the nuts and other vegetable matter associated with them had been accumulated at the time of the 25 foot beach.

Dr. David Ellis read a paper on "Fossil Moulds and Fossil Bacteria". He outlined briefly the characteristics of the living representatives of the two groups of organisms referred to, and said that it was about eighty years since fungi had been recognized in the fossil state and several species had already been named. The subject

had received attention from Worthington Smith, Felix, Williamson, and Renault.

Being particularly interested in the iron bacteria it had occurred to him to examine a series of microscopic sections of Mesozoic ironstones with the object of discovering whether they contained any evidences of the existence of members of that group at the period of formation. He had not succeeded in tracing iron bacteria in these rocks, but had found the remains of moulds which had possessed a similar power to deposit iron oxide on their membranes. The delicate hyphæ were found ramifying through fragments of organic matter, showing reproductive organs and branching portions. He found the evidence so definite that he felt justified in naming the organisms, but not in relating them to modern species. He had found these organisms in the ironstones of Lincolnshire and of Raasay. In examining a thin section of a nodule from the Gault, near Folkestone, he had detected the presence of bacteria, represented by both bacilli and cocci, whose size and characteristic appearance left no room for doubt as to their identity. The paper was illustrated by a fine series of micro-photographs.

In reply to points raised in the discussion by Professor Gregory, Mr. Tyrrell, and others, Dr. Ellis said that he did not think there was a possibility of his having been misled by deceptive appearances. He could not suggest how such delicate organisms had been preserved, but the fact remained that they were there in the rocks.

IV.—Liverpool Geological Society.

April 13, 1915.—W. A. Whitehead, Esq., B.Sc., President, in the Chair.

The following paper was read: "The Mineralogical and Chemical Constitution of the Triassic Rocks of Wirral." Part II. By H. W. Greenwood and C. B. Travis.

While confirming and extending the results recorded in the first part of the paper (Proc. Liverpool Geol. Soc., vol. xi, p. 116) the authors had established some very significant facts, the full discussion of which they postponed, pending further investigation. They were satisfied, however, that, contrary to the prevalent view, secondary silica played a negligible part as a true cementing material of the rocks, the most important agents in this respect being the carbonates of lime and magnesia. These were normal constituents of the Wirral Trias, and not due to secondary infiltration. Analyses of the Keuper Marls also invariably showed a high content of lime. Barytes was widely distributed throughout the rocks, and was not a surface manifestation.

On the whole the authors were led to the conclusion that the ingredients of the sandstones were derived ultimately from rocks of a granitoid character, but as regards the Upper Bunter and Lower Keuper, although the constituents were alike in both cases, their mode of occurrence seemed to indicate that the former had been derived from earlier formed sediments, and the latter directly from the erosion of an igneous area.

CORRESPONDENCE.

ZONES OF THE CHALK AREA OF NORTH-WEST MIDDLESEX AND EAST BUCKS.

Sir,—For some time up to about two years ago I was occupied, when occasion permitted, in zoning the Chalk area of North-West Middlesex and East Bucks. Latterly I have been too busy, and I find the chance of my ever being able to take up the work again very remote. I am therefore sending you a note of such results as were obtained.

The sections most carefully worked were—

(1) About 1 mile N.W. of Denham, in the most southerly Chalk outcrop.
(2) About 1 mile N. of Denham, just under the h 5 in the 1 in. drift sheet.
(3) Troy Mills, about 2 miles N of (2).
(4) Harefield Cement Works Pit.
(5) Harefield Gelatinous White Co.'s Pit.
(6) Springwell Pit.
(7) Pit on Golf Course at Sandy Lodge.

Marsupites and *Uintacrinus* were nowhere found, in spite of careful search. From Nos. 1 and 2 came several high-zonal *M. cor-anguinum*, and from Nos. 3, 4, and 7 low-zonal *cor-anguinum*. In Nos. 5 and 6, both of which have a section of about 80 feet from the pit floor to the top, the floor in each case being nearly at the same level above O.D., both *M. cor-anguinum* and *M. cor-testudinarium* were found, as well as passage forms, so that both these zones would seem to occur. *M. cor-testudinarium* was also found in an excavation below the level of the floor at Harefield. The junction of the zones can be conveniently taken at a band of comminuted mollusca and echinoids which occurs in both sections.

This band was only a few feet above the floor at Harefield, but at Springwell it was about half-way up, or nearly 40 feet above the floor. This gives a difference of 30 feet in a north–south distance of 1½ miles, or 20 feet to the mile. As *M. cor-anguinum* was found near Chorley Wood, nearly two miles north of Springwell, and the same species occurs near Watford, there must be a rather sharp flexure of the Chalk south of Rickmansworth, bringing up the lower zones.

Fossils are not common, except in the lower parts of pits 5 and 6, i.e. in the *M. cor-testudinarium* zone. Most characteristic are a flat broad-based pentangular variety of *Discoidea cylindrica* and *Echinocorys vulgaris*. *Parasmilia centralis* was not infrequent. The flints are very spongiferous.

Chas. E. P. Brooks.

"Homeleigh," 3 Roseleigh Avenue,
Highbury, N.

OBITUARY.

RICHARD LYDEKKER,

B.A. (Camb.), F.R.S., F.G.S., F.Z.S., J.P. Herts.

Born 1849. Died April 16, 1915.

It is with deep regret we have to record the death at Harpenden, in his 66th year, of our esteemed friend Richard Lydekker. He was for many years a fellow-worker in palæontology with your Editor, in the British Museum (Natural History), where by his

scientific labours he has left his mark on the Zoological and Geological Collections in both Departments.

Born in 1849, Richard was the eldest son of the late G. W. Lydekker. He entered Trinity College, Cambridge, 1869, where he passed second in 1st class Natural Science Tripos in 1871, taking his B.A. degree. He joined the staff of the Geological Survey of India in 1874, and during his residence there as an officer of the Survey spent much time in the field, and we have to thank him, amongst other excellent pieces of geological work, for a detailed account of the vast mountainous area comprised within the territories of Kashmir.

He commenced his labours in the domain of Vertebrate Palæontology, by a study of the Siwalik fossils, and was able to contribute numerous valuable additions to the classic work of Falconer and Cautley. Many other Tertiary Vertebrata, from various parts of India and Burma, have been examined and described by him. He has also given an account of the Pleistocene fauna of the Karnul caves, and has contributed to our knowledge of the Indian Mesozoic Reptilia. He returned to England in 1882, and took up his residence permanently at his family home, Harpenden Lodge, Harpenden, Herts. In the same year Mr. Lydekker married Lucy Marianne, the eldest daughter of the Rev. Canon O. W. Davys, M.A., Rector of Wheathampstead.

Shortly after this he commenced to study and catalogue the Fossil Vertebrata in the Geological Department of the British Museum (Natural History), and in 1884 completed vol. i of a series of five volumes on *The Fossil Mammalia in the British Museum*, the fifth volume being issued in 1887. From the Mammals he proceeded to the Fossil Reptilia and Amphibia, the catalogue of which was published in four volumes between June, 1888, and April, 1890. The final volume, on the Fossil Birds, he brought out in 1891, thus earning for himself with the Museum staff the good-natured sobriquet of "our lightning cataloguer". Indeed, Mr. Lydekker at that time was undoubtedly the most assiduous worker, as a scientific man, I think, that I ever met, and his catalogues of the vast collections of fossil vertebrates in the Museum are pioneer works of the greatest possible value to his successors.

With Professor H. A. Nicholson, Lydekker undertook a third and much enlarged edition of the former's well-known textbook of Palæontology, in two massive volumes, the second, on the Vertebrata, being by him. With Sir William Flower he collaborated in an excellent volume on *Mammals, Living and Extinct*, which appeared in 1891 (pp. 764). Later, on the recommendation of Flower, he visited the National Museum of Argentina at Buenos Aires, and there prepared and published, with the help of Dr. Moreno, the Director, "Descriptions of South American Fossil Animals" (for the Annals Museo La Plata). He assisted Sir William Flower in the rearrangement of the entire mammalian collections (after Dr. Günther's retirement) in the Zoological Galleries of the British Museum (Nat. Hist.), and continued similar work almost up to the time of his death. In 1896 he produced a volume entitled *The Geographical History of Mammals*, to which he attached especial importance, and of which he always hoped to publish a revised edition. His work